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The picture on the cover is of an olive tree surrounded and covered by locusts in the Fontana Settlement, Tripolitania.

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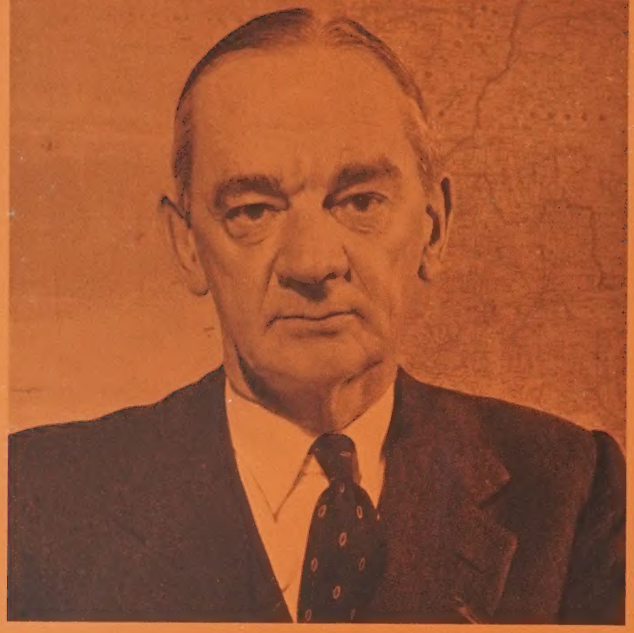


NEW DIRECTOR FOR ANTI-LOCUST RESEARCH CENTRE

On 31st March this year Dr. B. P. Uvarov, C.M.G., F.R.S., resigned the directorship, which he had held since its inception in 1945, of the Anti-Locust Research Centre in London. He has been succeeded by Dr. T. H. C. Taylor, D.Sc., who is pictured above. After reading zoology at what was then University College, Reading, and taking, successively, the B.Sc., M.Sc. and D.Sc. degrees of the University of London, Dr. Taylor was appointed to the Colonial Service in 1925, when he went to Fiji to work on the biological control of coconut pests (he specialised in biological control techniques for many years afterwards). In 1934 he was transferred to Uganda, where he worked mainly on insect pests of cotton and coffee. In 1944 he returned to England and went to the Commonwealth Institute of Entomology, of which he was Assistant Director from 1946 until joining the Anti-Locust Research Centre in 1953.

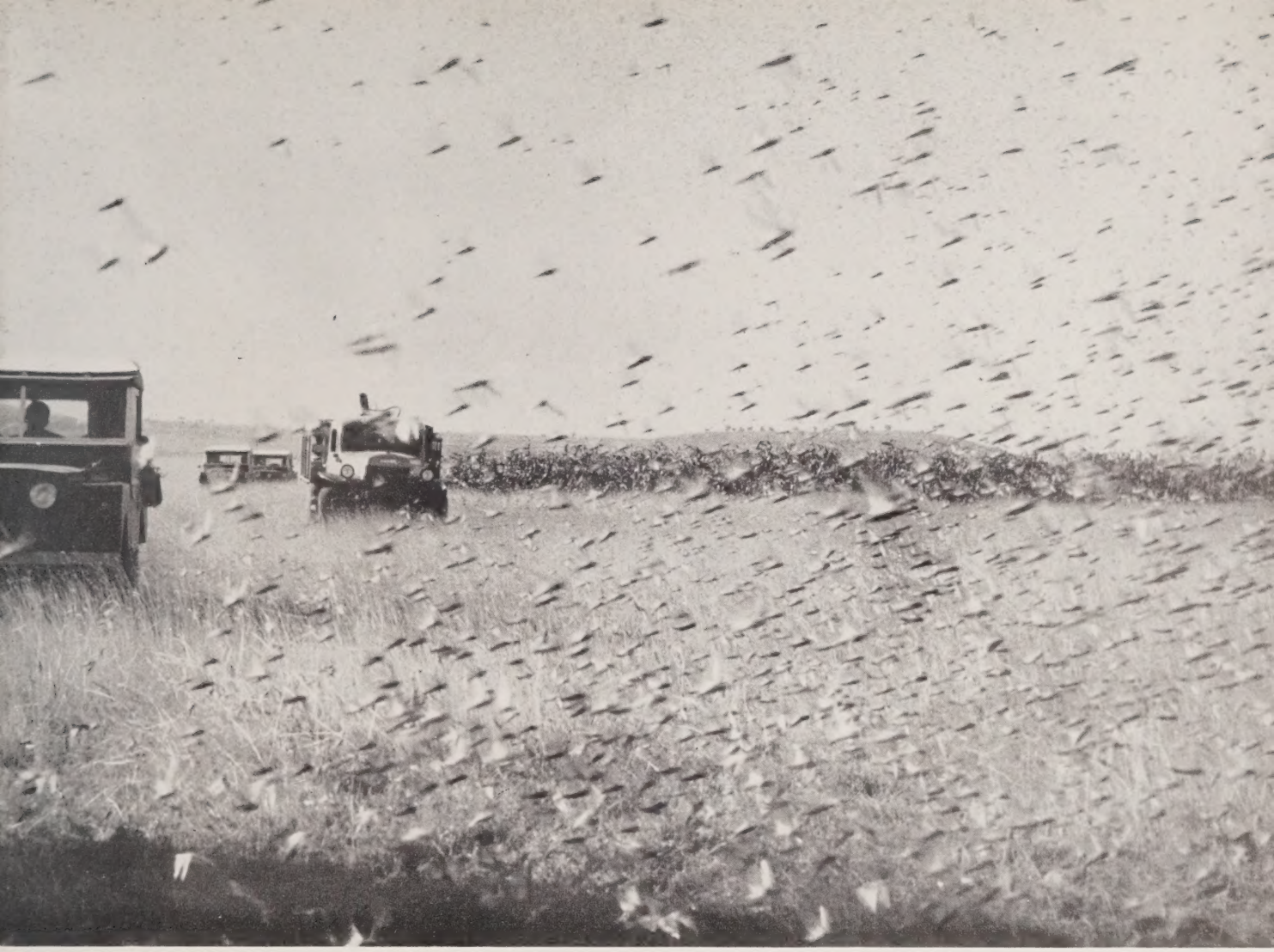
Of the work of the Anti-Locust Research Centre, Dr. Taylor has himself written that it 'conducts, sponsors and encourages research on locust ecology, behaviour, geography, physiology and taxonomy as well as control by insecticides. It receives regular reports of the movements and occurrences of locusts in the countries of Asia and Africa and from them prepares monthly summaries of the current situation and monthly forecasts of future developments for the benefit of all the countries concerned. [This service is now sponsored by the FAO.] It also serves as a centre of information on locusts and related insects, and publishes, or fosters the publication of, the results of scientific research concerning them. While its policy is directed towards the solution of the fundamental problems of the activities of locusts, it recognises that this is a long-term project and that the control of locusts by direct destruction is a practical necessity in the meantime'.*

* *World Crops* **10**, 2, p.45 1958.

A ground spraying unit moves into position fo

LOCUSTS AND THE WEATHER

by **P. T. Haskell,** Ph.D.
Anti-Locust Research Centre.



ttack on part of a desert locust swarm in Somaliland. Photo: C. Ashall, Desert Locust Survey.

Although it may be somewhat disappointing to the more romantic among us that grave discrepancies have been found between the locust of legend and the locust of scientific observation, yet enough of the former has been verified in the latter to make the story one of the most fascinating in biology. Many facets of this story have been and are being investigated, and those who are perhaps now disillusioned as to the locust legend may find consolation in contemplating the relationship—the alliance, it might almost be called—between locusts and another traditional enemy of man—the weather. It is ironical to find that that force of Nature with which man is constantly contending endows the locust with potentialities of movement and reproduction which make it the great menace it is. We are at last beginning to understand how this alliance comes about, and in so doing the truth of a statement made by Uvarov in 1931, in his classical work, *Insects and Climate*, has become apparent. 'The ecological conception of economic entomology', he then wrote, 'consists in the recognition of the injurious insect as an integral part, and even as a product, of its environment'.

Perhaps the main—and certainly the most obvious—characteristic of locusts is their mobility; it is in fact their fantastic powers of movement and migration which transform the relatively harmless sedentary grasshopper into a recognised international menace. In this respect, indeed, fact outweighs fiction, for who among the ancient originators of the locust legend could know, for example, that swarms of the desert locust, containing millions of insects weighing in the aggregate thousands of tons, could move for many weeks at a time as coherent entities, covering hundred of miles during this period? Such facts as these made a wider approach necessary in the study of locust movements.

Mobility

In spite of the work done on the relation of climate to insect biology, only in fairly recent years have attempts been made to investigate variations in the environment in terms of synoptic meteorology; one of the stumbling blocks in the application of such concepts is generally found in the absence or paucity of records of the distribution and movement of the species concerned. However, the Anti-Locust Research Centre in London has for 25

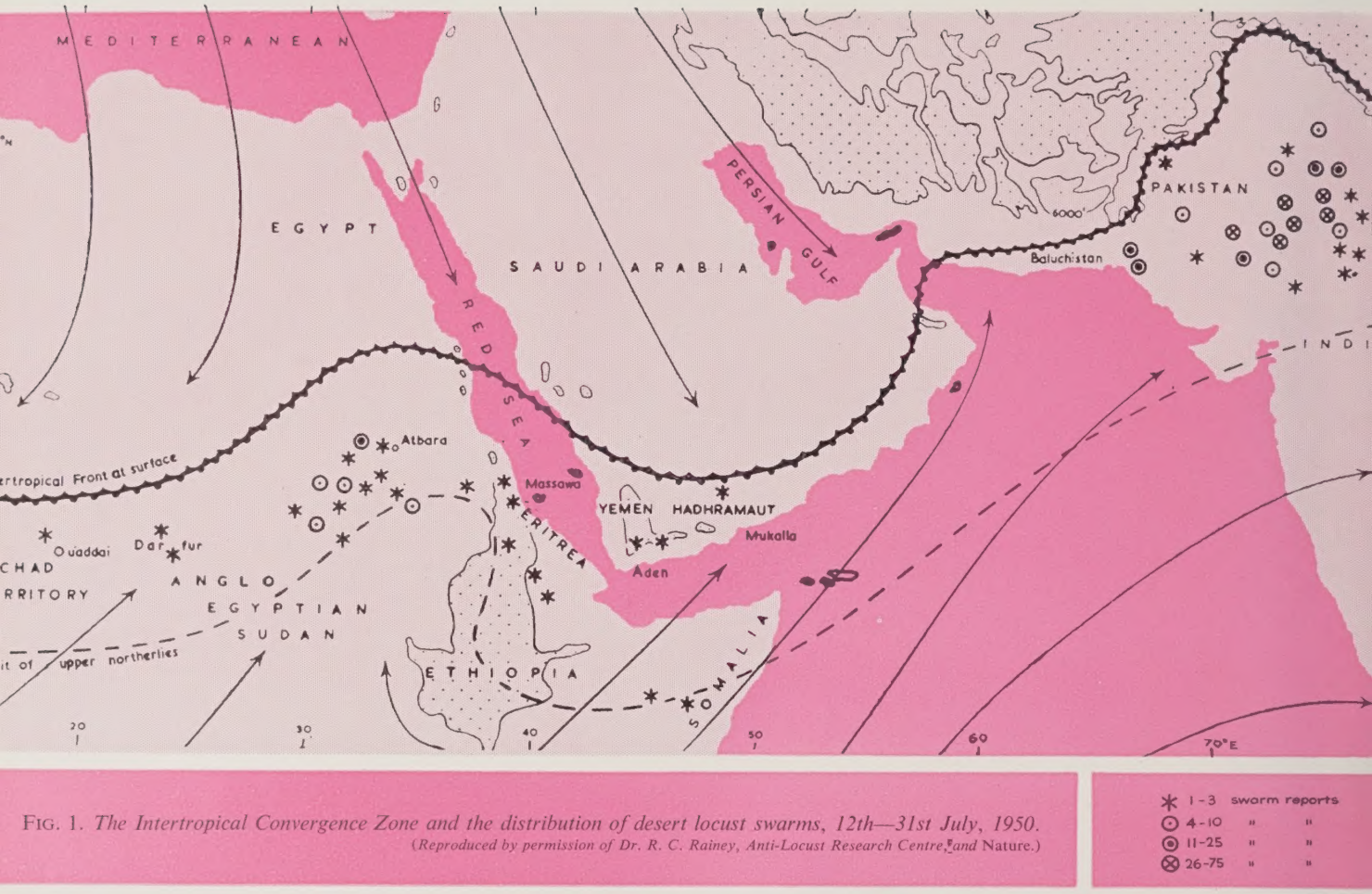


FIG. 1. *The Intertropical Convergence Zone and the distribution of desert locust swarms, 12th—31st July, 1950.*
(Reproduced by permission of Dr. R. C. Rainey, Anti-Locust Research Centre, and Nature.)

years been carrying out cartographic analysis of the distribution of the desert locust and for the past 15 years has been co-operating with the Desert Locust Survey organisation in Africa in carrying out experimental studies in the field of the behaviour of locust swarms. This work has underlined the amazing mobility of locust swarms; in the early part of 1952, for example, swarms produced in Ethiopia and Somaliland moved 2,000 miles to the north to breed along a belt extending from Jordan to Pakistan. In 1950, breeding on the Red Sea Coast of Saudi Arabia in the early months of the year produced swarms which reached Atbara in the Nile Valley in May, and then moved to Darfur, 700 miles to the south-west, 15 days later. Some swarms from this wave were afterwards believed to have reached French Equatorial Africa in the middle of June, thus moving 1,300 miles in a month.

Effect of Wind

Laboratory and field evidence on the flight performance of the desert locust suggests that while prolonged flight activity is a characteristic of the behaviour of gregarious adult locusts (1, 2) the maximum air-speed they can attain in still air is of the order of 12 m.p.h. and thus flights of the magnitude indicated above could only be undertaken in the absence of wind, against headwinds of a very low speed or down-wind; moreover, field observations suggest that locusts do not fly with any consistent orientation for long periods.

Nevertheless, the cartographic analysis of swarm movements at the Anti-Locust Research Centre revealed a reasonably consistent pattern of regular major swarm movements. This analysis, together with a comparison of swarm movements and current weather records for the areas concerned, led to the hypothesis that all major displacements of swarms take place down-wind (3). It was then found not only that regular displacements could be accounted for by the movement down prevailing winds but also that most of the exceptions to the generalisation could also be explained by assuming movement with non-prevailing winds. Perhaps the most striking exception concerns the northward movement of swarms in spring into North Africa and the Middle East against the prevailing northerly winds. The weather records show, however, that at this season the areas concerned are affected by intermittent depressions, moving eastward and characterised by the temporary substitution of warm

southerly winds for the cold northerlies. The hypothesis of down-wind movement received further support when it became possible in the field to make accurate observations of the movements of swarms from light aircraft flying above them and to correlate these with data on the local winds obtained by the release of pilot balloons in the area (4). The evidence so obtained emphasised the close relationship between the track of the swarm and the local prevailing wind.

Moisture Requirement

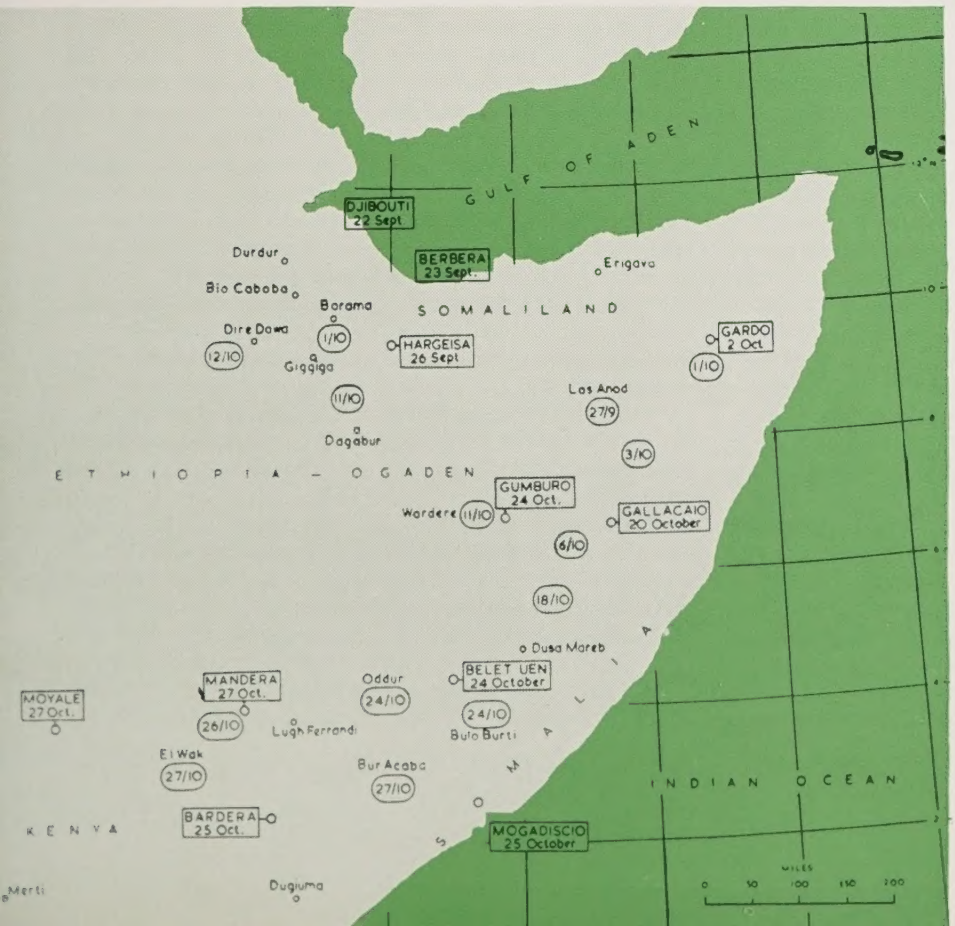
But the hypothesis of down-wind movement, fascinating though it was for the student of locust distribution, held still wider implications for the student of locust biology. It was known that the eggs laid by locusts contained far less water than that required for development—much less, in fact, than the hopper which emerges from the egg; the female, to ensure the viability of its offspring, must indeed lay its eggs in moist soil, from which the developing embryo can take up sufficient water to ensure growth. In dry sand, the eggs lose water and die. But cartographical analysis had shown the main breeding areas of the desert locust to be characterised by small and erratic rainfall of the order of 5-10 in. per year. Thus, to ensure successful breeding, the eggs have to be laid in synchronisation with the rainfall.

A more detailed consideration of the meteorological significance of down-wind movement provided the answer to this puzzle. Weather maps showing simultaneous observations of winds over wide areas indicate the presence of zones of convergence and divergence; in zones of convergence more wind flows into the area than out of it and the general movement of air within the zone is an ascending one, while in zones of divergence the opposite is true. Zones of convergence are marked in general by widespread rainfall, while zones of divergence are often characterised by dry weather. In general and on balance, winds within a few thousand feet of the earth's surface may be taken as blowing ultimately from zones of divergence to zones of convergence, and it therefore follows from the hypothesis of down-wind movement of swarms that these latter would tend to move into zones of convergence, and indeed to collect therein. Since, as remarked above, areas of marked convergence are in general areas of rain, the locust, by drifting with the winds, ends up by solving its problems of water-relations both for the egg-stage and for the young hoppers, which feed on the vegetation resulting from the rain.

Swarm Data

The data on the distribution and movement of swarms enabled this idea to be tested by comparing swarm records

FIG. 2. *Advance of the Intertropical Front and the movement of desert locust swarms in eastern Africa during September and October, 1950. Also see text.* (*Reproduced by permission of Dr. R. C. Rainey, Anti-Locust Research Centre, and* Nature.)



Date of first swarm record in area indicated ----- 24/10

Date after which N-E winds established at surface for greater part of each day at station named--- GALLACAIO 20 October

Camera, clock and anemometer set up for recording wind speeds; Kenya, 1954.

Photo: Gurdas Singh, F.A.O.

and synoptic charts in a convergence area. One such area, affecting some of the main breeding zones of the desert locust, is the so-called Intertropical Convergence Zone, the meeting point of winds originating on opposite sides of the equator, and Fig. 1 illustrated the relation between the swarms reported for the period 12th-31st July, 1950, when the Zone was relatively stationary, and the northern and southern limits of the area; it will be seen that nearly all reported swarms fall within the boundaries of the Zone. However, the Intertropical Zone is not a stationary area, but moves about according to season; the locust/weather hypothesis was therefore greatly strengthened when it was shown that there was an association between movement of the Zone and corresponding swarm movements (3).

Fig. 2 illustrates such an association: in September, 1950, the Intertropical Convergence Zone began to move southwards from the Gulf of Aden across the Horn of Africa and the square insets on the map indicate the dates on which north-easterly winds were established at the surface. The oval insets show the dates on which the first swarm records for the area were reported, and the correlation between these and the surface winds is clear. In November the Convergence Zone became stationary and no further sustained southward movement of swarms was noted during this time. The history of the evolution of this particular relationship between locusts and weather has been given here in some detail to illustrate the type of association which might be expected; it gives no idea of the difficulties of the work or the immense amount of time and labour necessary to originate and evaluate the original concept. The collection of sufficient data on the distribution and movement of locusts to test such a hypothesis is a task to be contemplated in terms of years rather than months; such difficulties are attendant on all attempts to relate distribution of insects to weather.

However, a start has also been made in this connection in respect of *Locusta migratoria migratorioides*, the African migratory locust. This insect has, unlike the desert locust, a relatively restricted outbreak area—the flood plains of the Middle Niger in West Africa—and until recently it was assumed that locust populations were virtually confined to this area throughout the year except when migrating swarms developed. However, these populations were subject to great fluctuations and the research staff of the *Organisation Internationale contre le Criquet Migrateur Africain*—the body set up to control the locust—sought an explanation of these changes (5). One suggestion (6) was that individuals of the solitary phase of the locust left the flood plains and migrated to the adjacent semi-desert regions, known locally as the Farimaké. This movement and the temporary colonisation it led to has been investigated by the method of marking large numbers of the adult locusts with special dyes and noting the time and place of their recapture (7). Despite the very large numbers marked the number of recaptures was small, owing to the very large area for dispersal. But the locusts recaptured were all taken in circumstances which supported the hypothesis that a two-way migration between the flood plains and the Farimaké occurs in this insect, and recently it has become apparent that these movements by the adults are probably aided by the wind.

The usefulness of such hypotheses as those outlined above in locust forecasting and control should be obvious. At present, such forecasting as is attempted is done on the basis of the analysis of previous records; application of the locust/weather relationship may enable swarm displacements to be predicted a week or more ahead, depending on the advance synoptic data available as to the movements of zones of convergence and the probable winds. In fact, the Desert Locust Survey organisation used the method in 1950 and 1951 in order to give five days warning to control units in the Northern Frontier Province of Kenya of the arrival of invading swarms from the north. Other aspects of the usefulness of the hypothesis may include the elimination of certain parts of outbreak areas where there is no need for constant scouting and control work; it may well be that some parts could be shown normally to have the expectation of a type of weather, at the critical time of year, such that no locust population could build up in them.

Climate Affects Development

So far in this brief survey we have dealt only with the effect of weather on the movements of locusts, but climatic conditions naturally play a major role during the development of the insect. Some studies have been made relating rainfall to the abundance of locusts and grasshoppers and here again availability of data over long periods has been one of the stumbling blocks. However, in cases where analysis of long duration records was possible interesting parallels have appeared. For example, records of grasshopper abundance in Kansas for the past 100 years (8), and records of outbreaks of the brown locust, *Locustana pardelina*, in South Africa for 14 years (9) have been examined in relation to rainfall, and in both cases the tentative conclusion was reached that the insects increased after dry years and decreased after wet ones.

In the case of the brown locust, the results were even more definite: population fluctuation was related to the amount of early summer rainfall in the season preceding the fluctuation, and not to the current rainfall conditions. Again, recent work (10, 11) with the moroccan locust, *Dociostaurus maroccanus*, in the field in Cyprus has underlined the delicate relationship between insect and climate, and in this case the amount and incidence of the winter rainfall greatly affected both the mortality and the fertility of the locust. Here, then, in embryo, would seem to be a powerful forecasting tool, the data for which are easily available and the results, if valid, of great importance in the planning of control campaigns.

The present and potential importance of the locust/weather relationship has recently been recognised by the setting up of a new service at the Anti-Locust Research Centre. This service, the International Desert Locust Information Service, which is partly financed by the Food and Agriculture Organisation of the United Nations, is aimed at the use of the current locust and meteorological data for forecasting and control. Also, the World

Meteorological Organisation has established a Technical Assistance Mission for Desert Locust Control in Nairobi, where two meteorologists are making a detailed study of data on locust movements and synoptic meteorology, with the co-operation of the Desert Locust Survey and the Anti-Locust Research Centre. Not the least interesting and important aspect of these developments is the value of combining the resources of two sciences, biology and meteorology, against a common enemy, and when we reflect on the trends in research summarised above we may see some irony of fate in the thought that the forces of Nature which conspire to intensify the locust menace may in the long run serve to help control it.

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VENEZUELA'S LOCUST INVASION

by **R. Guagliumi,**

*Ministerio de Agricultura y Cria, Caracas**

No invasion of the migratory South American locust (*Schistocerca paranensis* Burm.) has been reported in Venezuela during the last 40 years. Limited invasions of *Tropidacris latreillci* Perty have caused some concern and small outbreaks of *Schistocerca impleta* Walk., *Bucrates capitata* Deg. and *Nastonotus reductus* Br. occurred, but caused no more damage than other major pests which frequently attack agricultural crops of the country.

In April 1958 a severe locust invasion was reported in the savannas north of the Capanaparo river in the state of Apure, and according to the information received by the Ministry of Agriculture the locust swarms had been advancing slowly northward during the previous three years, traversing canyons and rivers on their way. As the first reports of these migratory locusts were received only recently, it was thought that the local guides of the area might have exaggerated the importance of the invasion and that perhaps only localised locust outbreaks were involved. However, a survey made from 15th to 17th April in the area between the rivers Cunaviche and Capanaparo showed that the reports were justified. Huge swarms of winged locusts were found concentrated on vast but isolated patches of ground. The swarms moved slowly but did not fly, feeding on the grasses of the savanna, leaving only their roots on the leaves of the few brushes and trees in the savanna and on the forests along the canyons.

Examination of a few specimens showed that this locust was not *Schistocerca paranensis* nor any other well-known species in Venezuela. This locust is smaller than *S. paranensis* and the tibia of the hind legs has a characteristic pink and blue colour. It was clear that this species was seldom found in Venezuela and that it was not only a new locust invasion but also a new pest which deserved special attention and investigation. Specimens sent to the Anti-locust Research Centre in London were identified by Dr. V. M. Dirsh as *Rhammatocerus viatorius* Saussure, an insect that has not been recorded previously as a serious plant pest or as a migratory locust.

According to information collected during the survey from the villagers and farmers, and especially from the guides looking after the cattle in the pastures of the state of Apure, these locusts were first observed three to four years earlier in various localities near the Colombian border, through which they probably entered Venezuela. Since then they increased in number and advanced northward, covering a large area and inflicting more damage every year. In addition to the region between the rivers Capanaparo and Cunaviche, the savannas of Elorza-Arichuna and of Santa Rosa seem also to be infested, and small infestations have been reported near Puerto Ayacucho and elsewhere.

The main damage caused by these locusts is the destruction of grassland, but during August and September a secondary but characteristic effect was the rendering of the meat and milk of the grazing cattle fetid and unpalatable, due to the large numbers of locusts and hoppers eaten by the cattle directly or while grazing. Fortunately, this secondary effect is only temporary and disappears during the dry season when the locusts are less numerous.

The damage caused to the grassland has until now had little effect on cattle raising, due to the large areas available for grazing and to the rapid recovery of the grass after the rains. The cattle breeders believe, however, that if the locust continues to multiply and extend its invasion area to the north, and if it is not checked by natural factors or control measures, sooner or later a huge locust invasion might occur, causing severe destruction of vegetative growth as it passes. The damage will then be comparable to what is experienced in other countries with migratory locusts, or to what happened in Venezuela about 40 years ago, when locusts invaded the whole eastern part of the country and British Guiana, destroying on their way the basic crops of the population.

The potential danger of this new locust outbreak is well appreciated and it is of outstanding importance, as the actual distribution area is only 150 kilometres distant from the new Guarico irrigation scheme, the future success of which is now being threatened by this plague.

This article is reprinted from* FAO Plant Protection Bulletin, **7, *2, November, 1958.*

LOCUSTS AND GRASSHOPPERS IN SOUTH AFRICA

A female brown locust, Locustana pardalina (*Walk*), *enlarged 2½ times. The most economically important species in South Africa, its breeding grounds extend over a wide area in the Cape Province.*

by **R. J. Neethling,** Ph.D.
Shell Chemical Company of Africa.

Locusts and grasshoppers belong to a very large group of insects known as the Orthoptera; other common insects which belong to this group include cockroaches, the praying mantis, stick insects and crickets. It is interesting to note that locusts are grouped in the family Acridiidae, and that the long-horned grasshoppers belong to the family Locustidae. The main distinction between these two groups is that the true locusts have short antennae, whereas those of the closely related grasshoppers are very long and slender. Generally speaking, locusts have come to be recognised as those 'grasshoppers' that at times congregate in large numbers to form swarms, while the grasshoppers show no gregarious tendencies.

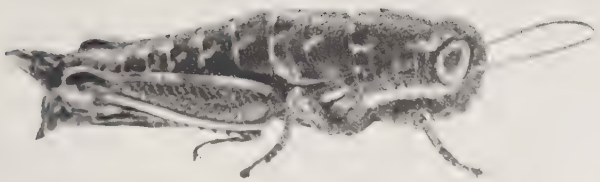
In a large country such as South Africa, it is not unexpected to find very great variations in climatic conditions: in certain regions desert or semi-desert conditions exist, while elsewhere sub-tropical conditions prevail. With such a wide climatic variation, conditions are ideal for a very large and varied insect population, in which the locusts and grasshoppers are well represented. At present, just over 600 different species of these insects have been identified, with probably many more to be added to the list. Although the species of locusts and grasshoppers are so numerous, it is fortunate for us in South Africa that only a few of them are of economic importance.

The locusts in general share certain characteristics, which make them most interesting insects to study. For many years, scientists were puzzled by the sudden appearance and disappearance of huge swarms of locusts in areas where no locusts were apparently present. It was not until the early 1920s, when Dr. B. P. Uvarov, in Russia, and Professor J. C. Faure, in South Africa, almost at the same time, but independently, discovered the existence of phases in locusts which explained this phenomenon. The observations of these two entomologists have since been confirmed by several independent scientists in different parts of the world. There are three phases through which locusts may pass—the gregarious or swarm phase, the transient phase, and the solitary phase. Whilst in any one of the phases the locusts may differ considerably in their habits and appearance from locusts in the other phases—so much so, that scientists have in many cases incorrectly identified phases of the same locusts as different species.

The Brown Locust

In South Africa, only two species of locusts are of economic importance, but for their control large sums of money are being spent. They are the brown locust, *Locustana pardalina* Walk., and the red locust, *Nomadacris septemfasciata* Serv. Of these, the brown locust is by far the most important. The breeding grounds of the brown locust are in the north-western part of the Cape Province, and cover a vast area, extending over many thousands of square miles. The greater part of this area, known as the Karroo, has little grass vegetation but is covered by numerous species of shrubs which provide excellent grazing for sheep. The Karroo is also the Union's most important producer of wool and mutton. The brown locust feeds on grass and grain crops and although it can cause considerable damage to what little grass and wheat is grown in the Karroo, it constitutes a much greater threat to intensively cultivated areas farther afield.

It has recently been estimated by Mr. A. Lea, Chief of the Locust Control and Research Section, that £60m.



A beneficial grasshopper, Lentula *sp.: it feeds on a noxious shrub known as the wax bush and keeps it in check. (Enlarged 2½ times.)*

A male red locust, Nomadacris septemfasciata *(Servo), enlarged 2½ times. Efforts by the International Red Locust Organisation to control this pest have been successful and it is no longer the threat that it was to South African agriculture.*

worth of crops are exposed to the depredations of the brown locust in South Africa each year. The importance of the brown locust was recognised at the beginning of the present century and in 1911 legislation was passed to enforce control measures against it; but it was not until several years afterwards that a permanent locust organisation with headquarters at Pretoria was established. Since that time, the brown locust has been closely studied and rigid control methods adopted to prevent its becoming a threat to the agriculture of South Africa.

Since 1920, the South African Government has spent, on average, £100,000 per annum on controlling the brown locust. In some years, the outbreaks have been much heavier than in others—for example, in 1951, £600,000 was spent on controlling this pest. The control of the brown locust is no easy matter, and for it to be effective it is essential that the locust control authorities keep a constant watch for any signs of breeding, an activity in which the farmers in the outbreak areas play an important part, passing information on to the authorities.

The female of the brown locust lays her eggs in dry soil where they can remain for periods of a year or more, if it does not rain. For the eggs to hatch, it is imperative that moisture reaches them; this is rather a providential arrangement, as it ensures that young grass shoots will be available for the young hoppers when they emerge. The young hoppers, if from parents of the swarm phase, and emerging in dense numbers, are at first light in colour, but soon afterwards they become almost black. Within several hours of emerging, the hoppers move from the breeding grounds in hopping bands. The bands generally move more or less in the same general direction, the individuals of each band always remaining closely together. The young hoppers, or nymphs, which are wingless, shed their skins five times, and each time grow bigger, until after the fifth month the adult stage is reached and wings are developed.

The adults of the different hopper bands congregate with other bands to form eventually enormous swarms which, if left undisturbed, will move from the breeding grounds in dense swarms, travelling inland for many hundreds of miles, even as far as the Northern and Southern Rhodesian territories.

If the hopper bands are dispersed, either as the result of control measures or by predators such as birds (of which the European stork is one of the more important) the individuals of the band disperse, become light in colour, and develop into the solitary phase. The adults of the solitary locust are generally smaller than those of the swarm phase locust, and are also more lightly coloured. The solitary phase locust shows a marked disinclination to fly and generally prefers to hop or crawl in search of food. It is these solitary individuals that will again give rise, in one or two generations, to locusts of the swarm phase.

The brown locusts are now—thanks to the Locust Control Organisation—so rigidly kept in check that no large swarms have been allowed to emerge from the breeding grounds for many years. A swarm of locusts is today rarely, if ever, seen in South Africa.

In order to control the brown locust, many tons of BHC are used. The hoppers are generally sprayed by teams of sprayers on trucks who spray hopper bands in the area allocated to them. The efficient control of the hoppers depends largely upon accurate information regarding the location of bands and thereafter dealing quickly with them:

if widespread rain occurs in the Karroo, it generally means that a heavy outbreak of locusts can occur over an area which is so extensive that it is impossible to deal with all the hopper bands. The bands which escape destruction proceed to develop to the adult stage and these will join up with other bands to form swarms. The swarms are then dealt with by the application of BHC from the air.

BHC has proved to be a most useful insecticide for controlling the brown locust. Since this insect occurs in areas which are often being grazed by sheep, it has been found that BHC can be applied in high enough concentrations to kill the locusts, but without any danger to stock feeding in the area. The effect of BHC on the brown locust is almost instantaneous, which is a great advantage, since it obviates the possibility of having to respray locusts, which would add to the cost of controlling them.

BHC and DDT are manufactured in South Africa by a Government-subsidised body which can produce them at very low cost. But although BHC has been found to be an excellent insecticide for the control of the brown locust, the locust research authorities are constantly searching for other insecticides that may prove to be even more effective.

The Red Locust

The brown locust is not the only locust that has threatened the agricultural crops of South Africa. The red locust, which breeds in isolated swampy areas in Northern Rhodesia and Tanganyika, has menaced the agriculture of South Africa on several occasions, and generally in years following heavy outbreaks of the brown locust.

The red locust, so called because of the colour of its wings, is bigger than the brown locust and also shows a preference for breeding in swampy grasslands. The hoppers migrate in bands by hopping from one blade of grass to the next and will only move along on the bare ground if no grass is available.

The red locust used to plague vast areas, extending as far south as Natal, where it caused considerable damage to the sugar cane. Control measures against the red locusts have cost the Union of South Africa as much as £1m. in one year.

In 1949 an international agreement was reached by those countries which, at one stage or another, were affected by the red locusts, to form an organisation that would deal with this pest. The headquarters of the organisation, the International Red Locust Organisation, are at present at Abercorn in Northern Rhodesia. Each country belonging to the Organisation contributes a percentage of the cost of carrying out control measures. Since these were introduced in the outbreak areas, the red locusts have ceased to be a major threat to agriculture in South Africa, and the last big swarm to invade South Africa was in 1945.

At present, aerial application of insecticides is largely used to control the locusts, DNOC being used as a contact insecticide against the adults. More recently dieldrin has been successfully used for the control of the hoppers by aerial application in swaths in those areas known to be infested with hoppers. The hopper bands, moving about in their constant search for food, at some stage or other move into the sprayed swaths, and are killed either by eating the sprayed grass, or by coming into contact with the insecticide.

Grasshoppers

In addition to the locust species mentioned above, there are numerous species of grasshoppers; these never show any tendency to become gregarious, but exist as individuals. It is quite possible that if all the individuals of one species were to band together, they would make quite a sizeable swarm, and would do appreciable damage. As it is, the damage—although still there—is spread over a vast area, and therefore to a large extent passes unnoticed.

It is perhaps worth noting that the solitary phase of the red locust has been observed over a number of years in an area West of Pretoria; but it appears that conditions are not suitable for breeding on a large scale, and there has never been any sign of congregation to form swarms.

The solitary phase locusts and grasshoppers generally tend to be more of a nuisance than anything else, chewing and damaging the foliage of numerous crops. But there is one species of grasshopper which at times does tend to become a fairly serious pest. This grasshopper is known as the elegant locust (*Zonocerus elegans* Thunb.)—so called because of its attractive colouring, which is in fact a warning to predators that it is unpalatable. It protects itself by giving off an offensive smell if interfered with in any way. These grasshoppers do sometimes show gregarious tendencies, but they never develop into the true swarming phase. They are sometimes pests in gardens, and also in crops such as cotton, where they can do considerable damage by defoliating the plants. They are extremely tenacious insects and in order to kill them it is necessary to use such highly toxic insecticides as parathion, or heavy applications of BHC.

From what has been said, it would seem that all grasshoppers and locusts are pests, and that they serve no useful purpose. This, however, is not always the case, as is illustrated by a species of grasshopper occurring in the Eastern Cape Province. This grasshopper is of considerable value to the local sheep farmers, for it so happens that in that area there is a particularly noxious shrub (the local name of which means wax bush) which tends to replace those shrubs which are selectively grazed by sheep. This grasshopper shows a distinct preference for the shrub; indeed, it will eat nothing else and so keeps it in check. Should this grasshopper disappear from the area, it is quite possible that sheep farming would also cease, unless the noxious bush could be kept in check by other means.

Acknowledgement

The author wishes to express his thanks to the Locust Control, and Control & Research Section of the Union Department of Agriculture, for specimens of locusts submitted to him.

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LOCUSTS AND GRASSHOPPERS IN AUSTRALIA

by **K. H. L. Key,** Ph.D.
Principal Research Officer
Division of Entomology, CSIRO, Canberra.

In their basic characteristics, the locust and grasshopper problems of Australia are similar to those of other parts of the world. These insects are pests of crops and pastures, whose numbers are subject to great fluctuations, so that we can speak of 'outbreaks' or 'plagues' separated by periods of remission. The prime cause of these fluctuations is the weather, which can act in a wide variety of ways to increase or diminish survival and reproduction rates of the insects and hence the rate of multiplication from one generation to the next.

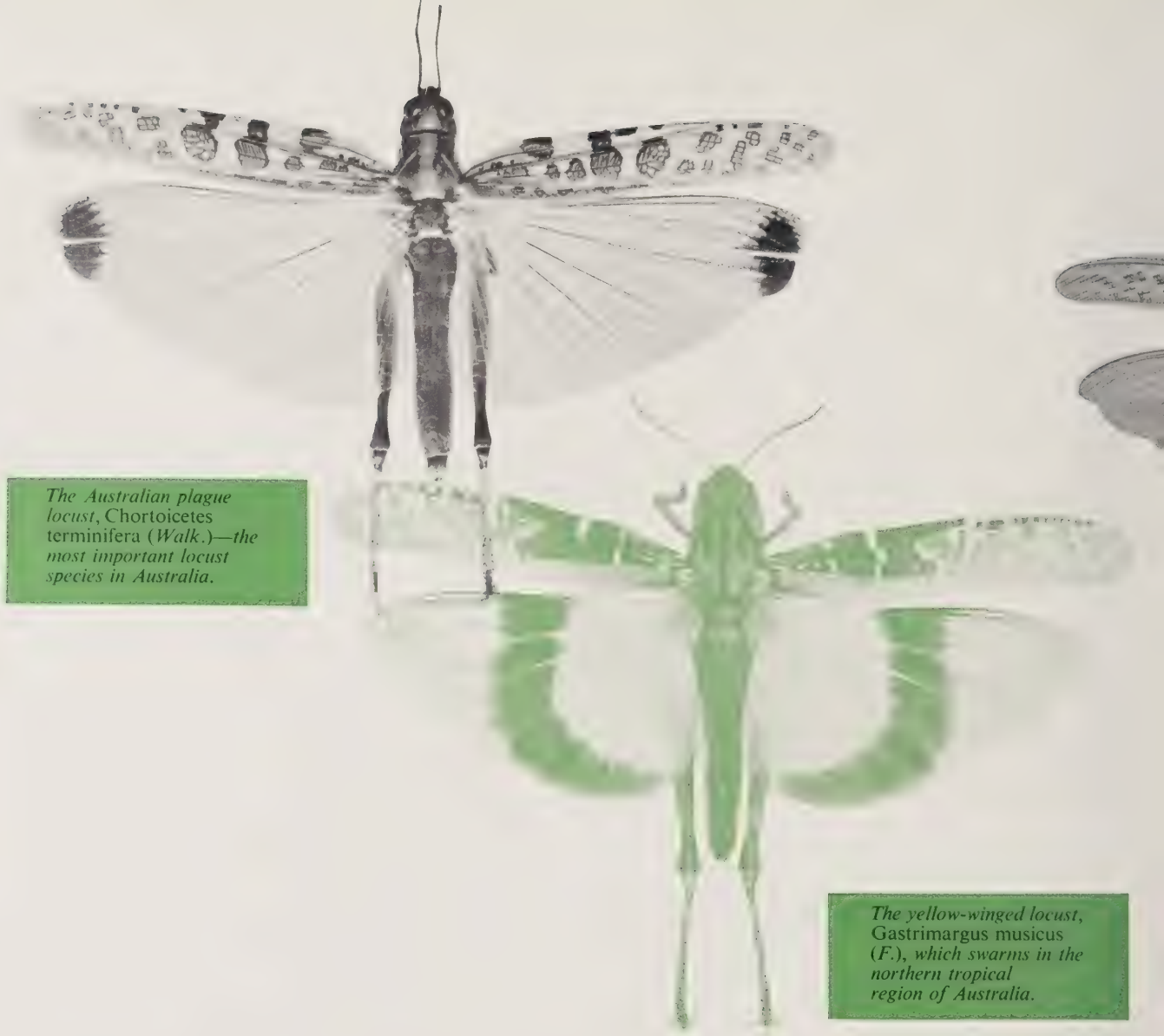
In the case of locusts, multiplication typically takes place in specific favourable areas, known as 'outbreak areas', which are usually situated outside the major agricultural regions. When the locust population of these areas reaches a certain critical density, swarms are formed which emigrate and may invade crop land. Thus in the absence of knowledge of the location of the outbreak areas and of a warning system based on that knowledge, the agriculturalist is liable to be faced with a sudden overwhelming invasion of the pest, for which he has been able to make no adequate preparation.

Grasshoppers differ from locusts in being essentially non-migratory, although they may be to some extent gregarious. Thus, to become pests of any crop they must be able to increase to injurious numbers within the cropped area, or at least in its immediate vicinity. However, the operations of agriculture are unfavourable to many species of grasshopper, which are thus perhaps more characteristically pests of pastures than of crops. In any event, the element of surprise attack is absent in the case of grasshoppers, whose control is consequently less difficult than that of locusts.

The special features of the problem in Australia stem from the inevitable biological and ecological differences between species and from the particular geographical and agricultural background. All but one of the injurious Australian species are confined to Australia and the neighbouring islands to the north. The exception is the migratory locust, *Locusta migratoria*, which, although of the greatest importance in Africa and Asia, is only a sporadic and minor pest in Australia. Broad concepts of ecology and control strategy may be valid for most species of locusts and grasshoppers, but their detailed application must rest on the results of intensive research into the peculiarities of each species. Investigations on the two chief pest species in Australia, *Chortoicetes terminifera* and *Austroicetes cruciata*, have been proceeding since the mid 1930s and a considerable body of useful knowledge has accumulated. Less comprehensive work has been done on *Gastrimargus musicus* and *Phaulacridium vittatum*.

From the point of view of the geographical and agricultural background, the Australian pest species fall into two groups: the Australian plague locust, *Chortoicetes terminifera*; the small plague grasshopper, *Austroicetes cruciata*; and the wingless grasshopper, *Phaulacridium vittatum*, are pests primarily (*Chortoicetes*) or solely in the well settled southern half of the continent, where transport and supply facilities are relatively good and where both the human population and the level of land values justify and facilitate control measures.

The yellow-winged locust, *Gastrimargus musicus*, the spur-throated locust, *Austracris guttulosa*, and *Locusta migratoria* swarm in the northern tropical region, where conditions as regards control are more comparable with those prevailing in Africa north of the Zambesi. However, there is a fundamental difference between the Australian situation and that in Asia and Africa, and that is that the



The Australian plague locust, Chortoicetes terminifera (*Walk.*)—*the most important locust species in Australia.*

The yellow-winged locust, Gastrimargus musicus (*F.*), *which swarms in the northern tropical region of Australia.*

human inhabitants are relatively prosperous, so that pest losses merely depress money income and never carry with them a threat of starvation or ruin. In this respect the Australian problem is more comparable with that in the United States.

Australian Plague Locust

By far the most important of the Australian species is the Australian plague locust, *Chortoicetes terminifera*. This locust is most abundant in the warm-temperate region of eastern Australia where a rainfall of 15-25in. is rather evenly distributed over the year. Its life-cycle is adjusted to this climate in that there is no obligatory diapause and only a moderate capacity for enduring drought in either the egg or active stages, while three annual generations may be produced under favourable conditions. More than 20 outbreak areas are recognised, of which the more important are situated in pastoral country in central and northern New South Wales. A valuable indicator of outbreak areas is so-called 'self-mulching' soil—a heavy, grey, friable type, chiefly formed on alluvial plains. It is mosaics of this soil type with compact soils that form the basis for the patchwork of bare oviposition habitat and tussocky food-shelter habitat characteristic of the outbreak-area environment.

Swarming in the main outbreak areas in New South Wales leads to migration predominantly in directions from north-east to south. This brings the swarms into a moister climate and at the same time into the agricultural regions—more particularly the wheat belt. The north-easterly trend may result in limited invasions of Queensland, but more important are the invasions of Victoria to the south, which may occur at any point along the Murray River from east of Albury to the South Australian border. Almost all the Victorian infestations have originated in this way from New South Wales outbreak areas. In Queensland the most important region affected is in the south-east of the State, and again the dominant directions of migration are from north-east to south; limited invasions of New South Wales may occur. In South Australia outbreaks are

The spur-throated locust, Austracris guttulosa *(Walk.); like the yellow-winged locust it swarms in the northern tropical region of Australia.*

relatively rare and appear to originate partly from an outbreak area in south-western Queensland and partly from a diffuse one in central South Australia. The predominant direction of migration is southerly.

Control Technique and Strategy

The technique of control has passed through much the same evolution in Australia as elsewhere. Before the war arsenical bran bait was in general use. Later this gave way to benzene hexachloride bran bait, which in turn has been supplanted in recent years by BHC water-based sprays. There has been a considerable development in New South Wales of a variety of spraying machines for producing wide swaths of this spray. In Victoria the accent has been upon aircraft spraying with oil-based BHC, using Dakota-type 'planes. Recently the air-spraying technique has been adopted in New South Wales also, but with light aircraft. Other of the newer insecticides, particularly aldrin and dieldrin, have been employed to a more limited extent.

The strategy of control has been different in the different States. Until the present outbreak, the strategy in New South Wales was essentially direct defence—i.e., crop protection—carried out by landholders with some assistance from the State, but with a distinct tendency for the State to undertake an increasing responsibility. In the present outbreak the emphasis is being placed on State action using light aircraft against flying swarms. In Victoria the strategy over the past 10 years has been to intercept invading swarms at the Murray River with Dakotas and to deal with any resulting infestations on the Victorian side of the border in the same way. In South Australia and Queensland direct defence is still employed.

Under the Australian system, technical advice and participation in these control campaigns is a function of the State departments of agriculture, which also undertake *ad hoc* research on insecticides and methods of distribution. The fundamental and long-term ecological research has been conducted by the Commonwealth Scientific and Industrial Research Organisation and to a lesser extent by the Waite Agricultural Research Institute, Adelaide. For a number of years, however, the CSIRO has been advocating the strategy of 'outbreak suppression'—i.e., the strategy of directing an intensive, highly organised, State-run attack on the early swarms of an outbreak, with the object of crushing it before it could get properly under way. This is the strategy used with such success against *Locusta migratoria* and *Nomadacris septemfasciata* in west and central Africa and with less striking success against *Locustana pardalina* in South Africa. The development of new insecticides and the improvement in the technique of aircraft spraying in recent years are making this strategy more practicable. It seems likely that it will be increasingly adopted in the future.

Outbreak Prevention

The CSIRO has also been interested in the more radical strategy of 'outbreak prevention', by modification of critical features of the outbreak-area environment to the disadvantage of the locust. Certain procedures involving the planting of trees and shrubs have been under test for a number of years. A difficulty has been to devise a test on a scale small enough to be practicable, bearing in mind the mobility of even non-swarming locusts and the difficulty of isolating the test area.

The species second in importance to *Chortoicetes* is the small plague grasshopper, *Austroicetes cruciata*. This grasshopper occupies the more arid part of the zone of mediterranean climate in southern Australia, where it is a pest of wheat and pastures. Its life-cycle is adapted to this climate, in a manner closely parallel to that of *Dociostaurus maroccanus* (the Moroccan locust of the Mediterranean region), by an egg diapause, which ensures that hatching will not take place during the unfavourable dry summer or the moist but cool winter. There is thus a single annual generation. The regions chiefly affected are south-western Western Australia, South Australia, north-western Victoria, and south-western New South Wales. Control has been effected with poison baits. In Western Australia importance has been attached to the ploughing of egg-beds.

Those who attended the conference at Norwich in July, 1957, when the formation of a new Royal Agricultural Society of the Commonwealth was discussed were:

Front row—(left to right): R. C. Warnes, S. Australia; G. F. Shirley, New South Wales; Sir E. Robins, S. Rhodesia; A. Millar, S. Rhodesia; Sir C. Webb, New Zealand; H.R.H. The Duke of Edinburgh; S. Hordern, New South Wales; B. McKenzie, Kenya; Lt.-Col. H. J. Cator, R.A.S.E.; E. B. Gray, Tasmania; D. Pratton, New South Wales; J. M. Thompson, R. Ulster.

Back row—(left to right): H. Eisen, R.A.S.E.; F. Russell, R.A.S.E.; Hon. C. Fellowes, R.A.S.E.; Alec Hobson, R.A.S.E.; Hon. E. Digby, R.A.S.E.; Sir J. Denby Roberts, R.Highland; C. York, R.A.S.E.; A. Hurd, R.A.S.E.; C. V. Dayus, New Zealand; W. A. Benson, R.A.S.E.; Lt.-Col. G. Blewitt, R.A.S.E.; J. E. Gibby, R. Welsh; T. Neame, R.A.S.E.; J. H. Everall, R.A.S.E.; Capt. H. Tupper, R.A.S.E.

A NEW ROYAL AGRICULTURAL SOCIETY

At a time when the future structure and activities of the Royal Agricultural Society of England, and in particular the future of the Royal Show, is the subject of so much discussion, it is especially interesting to reflect that this year's 'Royal' at Oxford marks what is virtually the second birthday of a new agricultural society—one of which little has so far been heard, but which may well come to play an important rôle in the spread of agricultural knowledge throughout the British Commonwealth.

The new society, the Royal Agricultural Society of the Commonwealth, owes its existence very largely to the wish of individual Commonwealth Royal Agricultural Societies to form an association for the interchange of views on agriculture. The Duke of Edinburgh's enthusiasm for the new venture (he was President of the RASE in 1957, when the new society was formed) has given great encouragement to the founders, and, besides consenting to become President, the Duke took a prominent part in writing the original draft constitution of the society.

Membership of the new society is open to all Royal Agricultural Societies within the Commonwealth; so far, 13 out of a possible 14 have joined: the Royal Agricultural Society of England; the Royal Highland and Agricultural Society of Scotland; the Royal Ulster Agricultural Society; the Royal Welsh Agricultural Society; the Royal Agricultural Societies of New South Wales, South Australia and Victoria; the Royal National Agricultural and Industrial Association of Queensland; and the Royal Agricultural Societies of Western Australia, Tasmania, New Zealand, Kenya and Southern Rhodesia.

Of these 13 societies, 10 were represented at the first two conferences in 1957, at which the original constitution of the new Commonwealth society was drafted, and representatives of nine attended a further meeting at last year's Royal Show at Bristol, when amendments were made to the draft constitution. The Bristol conference also decided that the entrance fee and annual subscription should each be £50; that the new society's secretary should be the secretary of the RASE—at present Mr. Alec Hobson—and that the next conference should be held in 1960. This is expected to take place in Sydney next April.

The society has as its main objects the 'encouragement, strengthening and improvement' of relationships between the various Royal Agricultural Societies of the Commonwealth; the 'promotion and assistance of the science of agriculture and animal husbandry'; and the holding of conferences for interchange of ideas and discussion of mutual problems. The society is particularly interested in improved methods of crop production and livestock breeding; import and export regulations affecting the movement of livestock and agricultural products and machinery between member countries; improvement of farm machinery; and exchange within the Commonwealth of young farmers and others connected with agriculture. Already a scheme is afoot for exchange and settlement of young farmers and technicians between England and Australia, and it is likely that before long similar exchanges will be arranged between other Commonwealth countries.

Aldrin, dieldrin and endrin toxicity to bees

by **A. M. H. Sanger,** *Shell International Chemical Company.*

Apart from their function as pollinators, bees are commonly regarded as important 'domestic animals'; it is therefore right that all who are responsible for spray programmes should be concerned to see that insecticides, many of which are toxic to bees, are not used in a way which will cause widespread damage to bee colonies. In the following article the author summarises the available data on the toxicity of aldrin, dieldrin, endrin and other insecticides to bees. He suggests that insecticides which are moderately toxic to bees can often be used at dosages safe to these insects and that where more toxic substances have to be used various precautions can be successfully taken to protect bees in the area.

There is no doubt that many agricultural chemicals have a detrimental effect on bees. Data collected by STUTE (17) in West Germany show that out of 2,119 reported cases of damage to bee colonies during 1951-1955, 1,198 were caused by plant protective measures. The problem, however, should not be exaggerated since in spite of the great number of reported cases of poisoning at most 0.5 per cent. of all beekeepers in Germany were affected. Stute's data are summarised in Table I.

Table I. **Cases of damage to bee colonies caused by chemical control measures in W. Germany, 1951 to 1955**

	1951	1952	1953	1954	1955	Total
Weedkillers	18	31	65	63	77	254
*Insecticides** Orchard pest control ..	33	45	48	52	34	212
Rape—pollen beetle, cabbage seed weevil	97	85	72	22	29	305
Forests—cockchafer campaigns	5	33	39	26	12	115
Potatoes—Colorado beetle	58	88	38	14	9	207
Broad beans—aphids ..	—	—	—	14	24	38
Turnips—*Piesma* sp. ..	—	—	—	7	5	12
Pastures—*Tipula* spp. ..	—	—	—	—	6	6
Miscellaneous	20	8	9	7	5	49
Total	231	290	271	205	201	1,198

*Mainly BHC and BHC/DDT mixtures

It should be noted that pre-blossom and post-blossom spraying in orchards can also cause damage to bee colonies if flowering weeds are present. Similarly, the honey bee does not visit flowering potato plants, but does visit flowering weeds in and surrounding the potato fields.

Table II. **Oral toxicity of some insecticides to worker honey bees (*Apis mellifera* L.)**

	Beran/Neururer (5) 24°C. (24 hrs.)		Eckert (6) 35°C. (72 hrs.)		Eckert/Tucker (7) 32°C. (72 hrs.)		Jones/Connell (11) 30°C. (24 hrs.)		Wiese (22)* 24°C. (24 hrs.)	
	LD 50 µg/bee	*Danger Index (Oral)*	*LD 50* µg/bee	*Danger Index (Oral)*	*LD 50* µg/bee	*Danger Index (Oral)*	*LD 50* µg/bee	*Danger Index (Oral)*	*LD 50* µg/bee	*Danger Index (Oral)*
Aldrin	0.329	16.5	0.25	12.5	0.45	22.5	0.24	12.0	0.30	15.0
Calcium arsenate	23.341	58.0	—	—	—	—	—	—	—	—
Chlordane	2.258	56.5	1.21	30.0	—	—	1.12	28.0	1.90	47.5
DDT	10.264	256.5	12.0	300.0	4.60	115.0	—	—	0.74	18.5
Dieldrin	0.325	22.0	—	—	0.22	14.5	0.27	18.0	0.15	10.0
Endrin	2.826	282.5	—	—	1.63	163.0	—	—	1.03	103.0
γ-BHC	0.097	6.5	0.15	10.0	—	—	0.08	5.0	0.06	4.0
Malathion	0.611	30.5	—	—	—	—	—	—	0.135	7.0
Parathion	0.050	5.0	0.07	7.0	—	—	0.04	4.0	0.09	9.0
Systox	2.420	242.0	—	—	1.18	118.0	1.48	148.0	0.68	68.0
Toxaphene	52.105	651.3	22.0	275.0	—	—	39.81	497.5	21.30	266.0

* *Apis mellifera unicolor var. adansoni* Latr.

Other countries have recorded similar experiences to those in Germany with the application of pest control chemicals and it is therefore not surprising that the toxicity of agricultural chemicals to bees has been studied extensively. The results obtained, with particular reference to aldrin, dieldrin and endrin, are summarised below.

Laboratory Data

Laboratory data are mainly concerned with the determination of the oral toxicity of insecticides or other compounds to bees, although some data on contact toxicity and fumigant effect also exist.

To determine oral toxicity the laboratory technique developed by ECKERT (6), sometimes with minor modifications, is usually followed.

Since laboratory techniques are not standardised for such factors as temperature, type of solvent used and observation period, widely different values have sometimes been found for the oral toxicity of the same compound to bees. Data on aldrin, dieldrin and endrin together with those of some other compounds have been summarised in Table II.

In particular BERAN and NEURURER (5) provide many data on the oral toxicity of insecticides to worker bees and the more susceptible nurse bees. If their results on worker bees, fed with 10 c.c. of insecticide/sugar solution, are taken, the insecticides tested can be grouped in the following decreasing order of toxicity: methyl parathion > ethyl parathion > diazinon > gamma-BHC > chlorthion · metasystox > dieldrin > aldrin > malathion > chlordane · systox > isopestox > endrin > DDT > schradan > calcium arsenate > toxaphene > lead arsenate.

As HÄFLIGER (9) points out, the toxicity of insecticides to bees should be considered in relation to the dosage rates at which these insecticides are used in the field. It is, however, impossible to establish a fixed dosage rate for any insecticide which would cover most applications: DDT may be used at 0.5 lb. per acre for pollen beetle control, but at 4 lb. per acre for the control of orchard pests; dieldrin may be used at 0.125 lb. per acre for grasshopper control but at 1 lb. per acre for fruit fly control. It is, therefore, necessary in all cases to consider dosage rates for specific pests on specific crops; taking cotton pest control in the USA as an example, the following approximate dosage factors may be established:

Methyl parathion, ethyl parathion, Systox, endrin	1	(0.25 lb. per acre)
Dieldrin, γ-BHC	1½	(0.375 lb. „)
Aldrin, heptachlor, malathion, chlorthion	2	(0.5 lb. „)
Chlordane, DDT	4	(1.0 lb. „)
Toxaphene	8	(2.0 lb. „)
Calcium arsenate	40	(10.0 lb. „)

With the aid of these dosage factors it is possible to calculate a 'bee danger index (oral)' defined as the oral LD50 value in µg per bee multiplied by 100 and divided by the dosage factor for a given insecticide. Danger indexes calculated in this way for the USA cotton crop have been given in Table II.

But oral toxicity is only one factor which determines the extent of the poisoning of bees by insecticides; obviously contact toxicity and possibly the fumigant action of the insecticides also play an important part. Contact toxicity may be determined in various ways, but topical application of the insecticides gives data which can be compared with those on oral toxicity:

Table III — **Results of topical application of insecticides to honey bees**

	Beran and Neururer (5)		Wiese (22)	
	LD50 µg bee (tarsus)	*Danger index (topical)*	*LD50 µg/bee (thorax)*	*Danger index (topical)*
Aldrin	0.149	7.5	0.800	40.0
Chlordane	1.493	37.0	7.030	176.0
DDT	9.192	230.0	2.006	50.0
Dieldrin	0.150	10.0	0.414	27.5
Endrin	2.007	201.0	1.311	131.0
γ-BHC	0.183	12.0	0.110	7.0
Malathion	0.517	26.0	0.094	5.0
Parathion	0.111	11.0	0.088	9.0
Systox	1.111	111.0	0.842	84.0
Toxaphene	14.530	182.0	151.000	1,888.0

Other contact toxicity data as determined by the toxicity of insecticide deposits are given by BERAN and NEURURER (5) and PALMER-JONES (15), and as determined by spraying or dusting bees by JONES and CONNELL (11), ANDERSON and TUFT (1) and ATKINSON and ANDERSON (4).

Fumigant action has been investigated by various research workers (11, 15, 22) who found in general that γ-BHC, aldrin and chlordane are most dangerous in this respect. Although fumigant action may be important in the laboratory, it is rather doubtful whether this effect is of much importance under field conditions.

Summarising, so far as aldrin, dieldrin and endrin are concerned it seems clear on laboratory evidence that aldrin and dieldrin are highly toxic to bees, although less so than γ-BHC or parathion. Endrin is surprisingly only moderately toxic to bees and at 0.25 lb. per acre endrin is apparently less toxic than Systox at the same dosage rate and than chlordane or DDT at 1 lb. per acre, although it is still more toxic than toxaphene at 2 lb. per acre. Toxaphene is in all instances the least toxic to bees of all the modern insecticides.

Field Observations

Field trials on the toxicity of insecticides to bees are difficult to carry out. WEAVER (19) obtained good results using large cages; other workers count dead bees at the hives, taking care that the apiary is adjacent to the field so that poisoned bees are able to reach the hives before becoming incapacitated. Dead bee counts are also carried out in the treated fields.

Whatever method is used it is quite clear from published literature that aldrin and dieldrin, and in particular the latter, are highly toxic to bees when applied in the field even at such low dosage rates as 0.25-0.5 lb. per acre. At these rates dieldrin may give mortalities of 30-50 per cent. and aldrin of up to 25 per cent. To cite a few examples: LIEBERMAN *et al.* (13) found that aldrin at 2 oz. per acre caused an estimated kill of 22 per cent. of the field force and dieldrin at 1 oz. per acre caused a 36 per cent. kill. WEAVER (20, 21) found that six applications of 2½ per cent. dieldrin dust at an average of 13 lb. per acre caused a mortality of 56.6 per cent of the bees in the nucleus. KNOWLTON *et al.* (12) found that aldrin at 0.53 lb. per acre gave a 19.0 per cent. kill of the bees and dieldrin at 0.56 lb. per acre a 107.1 per cent. kill.

ECKERT and TUCKER (7) note that the application of dieldrin at ½ lb. per acre (7) against the rice leaf miner in California caused an estimated reduction in bee population of some apiaries of 25-50 per cent., while other colonies appeared to be uninjured. ANDERSON *et al.* (1, 3) found that no apparent damage to honey bee colonies resulted when dieldrin was applied at 0.33 lb. per acre to citrus, with the hives located in the citrus orchard, but they thought that the results were due to the small quantity of material applied to a relatively large amount of foliage. An unpublished report states that a bee mortality of 10 per cent occurred after the application of 300 gm. dieldrin per hectare on flowering colza in Holland when beekeepers were not warned to close their hives.

Little field evidence is available on the toxicity of endrin to bees. LIEBERMAN *et al.* (13) found that the application of endrin at 0.25 lb. per acre as a morning spray caused a 13 per cent. mortality of the field force. RASKIN (16) found no abnormal mortality of bees inside and outside hives after the application of 4-5 endrin sprays at fortnightly intervals at 0.5 lb. per acre on cotton in Israel. VAN DER PLANK (18) states: 'Endrin is very lethal to all ants and wasps, but not so toxic to honey bees, as was shown when three colonies of honey bees, *Apis mellifera*, nesting in the roofs of houses were heavily sprayed with 5 per cent. endrin in Sovacide F. Although reduction in the colonies was noticed, the attempt was a failure. A similar effect was noticed when two exposed colonies in the 18-acre area were sprayed with the 1 per cent. formulation, and in this case, the colonies appeared to increase.' The absence of further reports on the poisoning of bees by endrin leads one to the conclusion that this insecticide is fairly safe in this respect.

Discussion

Many factors determine the toxicity of insecticides to bees in the field and the subject has been well reviewed by HOCKING (10). The importance of some of the factors is still subject to discussion in view of the many contradictory findings. It is still not known whether dusts are more toxic than sprays or vice versa when applied in the field, and conflicting statements have been made on the repelling action of insecticides, etc. It is certain that much research is still needed into ways and means of applying insecticides in the safest possible manner.

Some countries, in the meantime, have introduced legislation to prohibit the use of insecticides, with certain exceptions—toxaphene is an example—on flowering crops. Although there is something to be said for this course of

Table IV. Toxicity of pesticides to honey bees

GROUP 1

Highly toxic materials that should not be used when there is a possibility of poisoning bees at treatment time or within a few days thereafter

Aldrin	DDVP	DNOSBP (DN-211)	Lindane
BHC	Diazinon	EPN*	Metacide*
Calcium Arsenate*	Dibrom	Guthion*	Methyl Parathion*
Chlordane	Dicapthon	Heptachlor	Parathion*[1]
Chlorthion	Dieldrin[1]	Lead Arsenate*	Sevin[1]

GROUP 2

Highly toxic materials that can be used around bees when certain precautions are used

Di-Syston*	Phosdrin*[1]	TEPP*
Malathion[1]	Sabadilla	Thimet*

GROUP 3

Moderately toxic materials that can be used around bees if timing and dosage are correct, but should not be applied directly on the bees in the field or at the colonies

Chlorobenzilate	DDT[1]	Korlan	Thiodan[1]
Co-Ral	Endrin[1]	Perthane	Toxaphene[1]
Cryolite	Ethion (Nialate)[1]	Tartar Emetic	Trithion[1]
DDD (TDE)	Isodrin	Tedion	

Relatively nontoxic materials that can be used around bees

Allethrin	Dilan	Methoxychlor	Ryania
Aramite	DMC	Mitox	Sulfur
Bordeaux Mixture	DNOCHP (DN-111)	Monuron (CMU)	Sulphenone
Captan[2]	Dylox (Dipterex)[1]	Nabam[2]	Systox (Demeton)*[1]
Copper Oxychloride Sulfate	Ferbam[2]	Neotran	Thiram[2]
	Genite 923	Nicotine	Zineb[2]
Copper Sulfate (Monohydrated)	IPC[2]	OMPA	Ziram[2]
	Karathane	Ovex (Ovotran)	2,4-D*[2]
Cuprous Oxide[2]	Kelthane[1]	Phostex	2,4,5-T*[2]
Cunilate	Maneb[2]	Pyrethrins	
Delnav[1]	MCP[2]	Rotenone	

* Permit required by State regulation for most uses of these materials. Permit for 2,4-D and 2,4,5-T as weed treatments but not as hormone sprays on citrus.

[1] These materials field and laboratory tested; all others just laboratory tested. Further field testing may change the group location of some of the materials.

[2] Data obtained from other research workers.

action, since any risks due to incorrect application of an insecticide are avoided, it excludes the use of more efficient insecticides and leaves much to be desired for the intelligent and responsible farmer or contractor. In the first place, the toxicity of insecticides to bees is dependent on the dosage rate (ATKINS and ANDERSON [4] for example) and it should be possible to establish maximum safe dosage rates for moderately toxic insecticides—e.g., DDT, chlordane, Systox, schradan, isopestox and endrin which are now excluded by law from general use in certain countries.

Secondly, countries where no specific legislation on this matter exists, usually recommend some simple precautions when insecticides are applied to crops in bloom: these include early morning or, still better, early evening treatment of the crop; removal of beehives from fields to be treated; and keeping the bees locked up in their hives for as long as possible. As the temperature in a beehive may rise very quickly and kill the bees, it is seldom possible to keep bees in ordinary hives for more than a day, though in specially ventilated hives, bees have been kept for more than three days without harm.

All these recommendations involve a warning system for which the farmer or spraying contractor is responsible. In practice this system seems to work well and in some countries colza in bloom, for instance, is still being sprayed with γ-BHC or dieldrin, and although casualties do occur occasionally, they are by no means as serious as would be expected from the high bee toxicity of these compounds.

Recently ANDERSON and ATKINS (2) have given a classification of agricultural chemicals based on their toxicity to bees which supports these views and which is reproduced in Table IV.

Finally, it must be noted that no information is available

on the toxicity of aldrin, dieldrin and endrin to wild bees. According to LINSLEY *et al.* (14) *Nomia*, *Megachile*, *Melissodes*, *Anthidium* and *Agapostemon* are more resistant than honey bees to DDT, but LIEBERMANN *et al.* (13) have noted that toxaphene although not toxic to *Nomia* was highly toxic to *Melipona*.

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Fighting Malaria in Mexico

More than 30 million children and mothers were protected against malaria last year under disease control programmes aided by the United Nations Children's Fund (UNICEF.), it has recently been reported.

Of allocations amounting to $22,600,000 approved by the Fund, the largest was $2,420,000 for malaria eradication in Mexico. This money is providing insecticides and spraying equipment for the third year of total coverage of malarious areas in a national eradication campaign which, it is estimated, has already reduced the number of deaths caused by malaria from 25,000 a year in 1950-54 to 6,500 in 1957.

In addition to allocating these funds to Mexico, UNICEF approved aid for malaria eradication campaigns in 32 other countries during 1958. Most of these countries are in the Americas and the Eastern Mediterranean, where regional programmes have been launched in an effort to eradicate the disease before vector mosquitoes develop resistance to insecticides.

An article on malaria eradication is published in this issue (p. 74)—Editor.

'Variety'—not 'Strain'

Following recommendations in the International Code of Nomenclature for Cultivated Plants, the National Institute of Agricultural Botany has suggested that the use of the terms 'variety' and 'strain' should be standardised.

The term 'strain' is now thought to be unnecessary and it is suggested that, where inherited differences can be found, 'variety' is the appropriate word. As a result of this decision the products of the Welsh Plant Breeding Station are now referred to as the Aberystwyth 'S' *varieties* of grasses and clovers.

The NIAB has also suggested that variety names should be shown in ordinary Roman type with capital initial letters; this is in order to avoid confusion with the Latin names of botanical species which are normally printed in italics, with a capital initial letter for the first word and a small initial letter for the second.

Fixation of Nitrogen

It has for long been known that plants of the family Leguminosae are able to "fix" nitrogen from the soil atmosphere to form proteins, and that they do so through a symbiotic relationship with bacteria living in root nodules. What is far less widely known is that there is much evidence to suggest that nitrogen fixation takes place on a considerable scale during the growth of many non-leguminous plants.

In the first of the two following articles, the author describes studies which, under her direction, have been carried out at the Plant Physiological Research Institute, University of Pretoria, on symbiotic nitrogen assimilation in legumes. The South African Department of Agriculture has, over a period of years, carried out field trials with indigenous and foreign legume species in an effort to find the most suitable types for ley farming and other purposes under South African conditions; but it was only in 1950 that fundamental research on legumes and nitrogen assimilation was started at Pretoria, and little detailed work was done before 1953. Professor Mes' article summarises the work which has been done since then.

In the second article, Dr. Stevenson describes field observations and pot experiments carried out in New Zealand at the Cawthron Institute, from which it seems clear that soil nitrogen fixation occurs during the growth of many plants without root nodules. She briefly postulates theories on the mechanism of nitrogen fixation by non-legumes, but points out that until more work has been done little will be known about this subject.

The studies at both Pretoria University and the Cawthron Institute have been made possible by grants from the Nuffield Foundation.

Symbiotic Nitrogen Assimilation in Legumes

by **Margaretha G. Mes,** Ph.D.
University of Pretoria, Transvaal.

The importance of legumes in agriculture has been recognised for many centuries, for the vegetative parts and seeds of these plants provide palatable food with a high protein content for animal and human consumption. It was only towards the end of the last century, however, that it was discovered that most legumes, through a symbiotic relationship with bacteria living in nodules on their roots, are capable of using the free nitrogen present in the soil air to form their proteins.

Although legumes can function as nitrogen factories they can do so only when infected with the appropriate bacteria—the so-called rhizobia. Favourable climatic and soil conditions are also a necessity, and a particular *Rhizobium* strain and environmental conditions most suitable for one kind of legume may be unsatisfactory for another kind. Studies on the conditions required for optimum growth and nitrogen assimilation of various legumes have been carried out in many different parts of the world, but much still remains to be done.

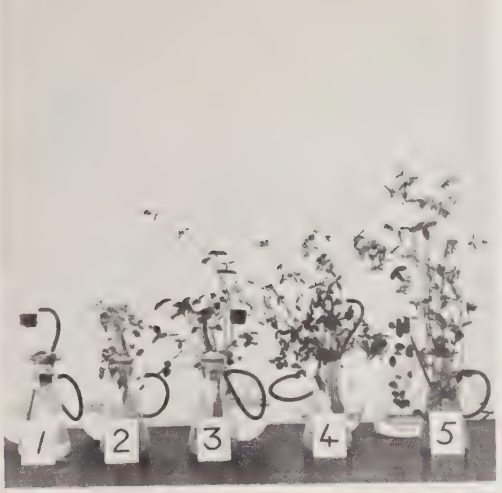
Satisfactory growth of the plants above the soil is often taken as evidence of the presence of effective nodules and satisfactory free nitrogen assimilation, but it is quite possible for nodules to be absent from legume roots, or ineffective, and the plants may be absorbing and thriving on nitrogen compounds present in the soil, as do other plants. Under such conditions legumes deplete rather than add to the nitrogen content of the soil.

Another not uncommon misconception is that most of the nitrogen assimilated by the plants is concentrated in the roots where the nodules are situated and that, if the tops are harvested and only the roots are left in the soil, the benefit to succeeding crops will be nearly the same as when the whole plant is ploughed in. In reality, more often than not, only 10-20 per cent., or even less, of the total nitrogen in the plants is found in the roots, depending partly on the relative development of tops and roots.

Studies With Rhizobia

Distribution and Effectiveness of Rhizobia. One of the first aspects to be investigated when the work at Pretoria began was the presence and distribution of rhizobia in South African soils and the effectiveness of the strains. Soil samples collected from many different localities were mixed with vermiculite, and seeds of up to 60 different legume species were sown in the mixtures in pots. When

Crotalaria ochroleuca *growing in a nitrogen-poor soil.* Left, *uninoculated plant;* right, *plant inoculated with* Rhizobium.



Clover, Trifolium pratense, *growing in sterile water cultures without nitrogen.* Left, *uninoculated control; other four cultures inoculated with different strains of* Rhizobium. *This picture illustrates the difference in degree of effectiveness of various* Rhizobium *strains in sterile water cultures.*

Cowpea, Vigna sinensis, *growing in vermiculite watered with a nitrogen-free nutrient solution.* Left, *uninoculated control; other four cultures inoculated with different strains of* Rhizobium. *This picture illustrates the difference in degree of effectiveness of various* Rhizobium *strains in vermiculite cultures.*

the developing seedlings formed nodules, the responsible *Rhizobium* strains were isolated in pure culture.

The results of these experiments, spread over a few years, consistently showed, first, that rhizobia capable of infecting the more commonly used legumes—peas, beans, cowpeas, vetches and lucerne—were present in most cultivated soils, although not necessarily in great numbers or as very effective strains. *Rhizobium* strains capable of infecting less common legumes (*Astragalus sinicus, Centrosema pubescens, Crotalaria paulina, Desmanthus virgatus, Leucaena glauca, Onobrychis sativa*) were nearly always absent. Secondly, the experiments showed that soils which had been under cultivation for relatively long periods generally contained a much greater variety of rhizobial strains than virgin soils. The problem of whether new rhizobia strains were brought in either by inoculated seed during the years of cultivation, or by any other means, or whether rhizobial strains gradually adapt themselves to new hosts, is an interesting one which cannot easily be solved.

A strain's power to infect does not necessarily imply that it is effective. A *Rhizobium* strain may produce nodules on a particular legume and yet be incapable of assimilating free nitrogen. Such ineffective nodules can be recognised because they are white inside instead of pink and they are usually also much smaller than effective nodules. The effectiveness of many hundreds of rhizobia for more than a hundred different species of legumes has been tested during the past five years in sterile water cultures, in pot cultures with vermiculite or a nitrogen-poor soil, and in field trials. (See Figs. 1, 2 and 3.)

Commercial Inoculants. The effectiveness of *Rhizobium* strains from South African soils was compared with commercial inoculants and also with strains obtained in pure cultures from Europe. Imported commercial inoculants often suffered from three defects. First, in most cases the number of rhizobia in the containers had decreased to an undesirable degree when marketed, possibly due partly to unfavourable temperature conditions during storage and transport to South Africa. Secondly, the preparations using a peat base sometimes contained other micro-organisms such as *Actinomyces* species or *Bacillus mesentericus*, which were found to be antagonists of rhizobia (see Fig. 4); it is possible that the antagonists are harmful to the rhizobia in the inoculants and later in the soil. Thirdly, the commercial inoculants for any particular so-called inoculation group seldom, if ever, contained all the *Rhizobium* strains necessary to nodulate effectively all the legume species and varieties in that group.

Cross-Inoculation Groups. The original cross-inoculation groups into which legumes were divided have a number of limitations and the establishment of more groups or sub-groups has been proposed. Our own studies at Pretoria have included experiments with many different genera and species said to belong to the cowpea cross-inoculation group; several varieties of a number of species of lupins and vetches; many species of *Trifolium, Crotalaria* and *Medicago*; and a number of varieties of peas and beans. In all experiments it was found that isolated strains of rhizobia effective for a particular legume were more often than not ineffective on a genus or species belonging to the same cross-inoculation group and even on another variety of the same species. Moreover, the effectiveness of strains on legume species or varieties was often not reciprocal.

Role of Host Plants. A dominant role in symbiotic relationship may be played by the host plant. For example, in a test, plants of *Trifolium alexandrinum* nodulated equally effectively with eight of eleven *Rhizobium* strains tested, whereas effective nodules on *Trifolium hirtum* were produced with only one of these same strains. Trials are in progress to discover whether the tops or the roots of plants play a dominant part in determining the specificity of a host plant for a particular *Rhizobium* strain. (*Continued on p. 66*)

An agar plate which was overgrown with rhizobia colonies and then infected with Bacillus mesentericus *in the shape of a cross. The rhizobia have disappeared in the areas adjoining the cross.*

Oats growing in vermiculite cultures. Control plants on extreme left (No. 1) growing with a complete nutrient solution and on extreme right (No. 5) with a nitrogen-free nutrient solution. In the three middle pots red clover plants had been grown with a nitrogen-free nutrient solution. In the pot on the right (No. 4) the clover roots were removed before the oats were sown, and in the other two the clover roots were left in the vermiculite and the oats sown.

Above: Hairy vetch, Vicia villosa, *plants. Left, plant growing in a 12-hour day; right, a plan growing in a 20-hour day.*

It was thought that the poor nitrogen fixation of certain nodulated plants might be due to an inherent low concentration of one or more vitamins in such plants, but investigations have so far yielded negative results.

It is possible that *Rhizobium* strains may adapt themselves, by selection, to particular host plants in certain restricted localities, and the possible importance of genetic characteristics and of geographical or ecological factors should prove a fruitful field for further research.

Survival of Rhizobia in Soil. The likelihood that native *Rhizobium* strains become adapted to the environmental conditions in a particular area has been investigated. Soil, sand and vermiculite samples inoculated with *Rhizobium* strains isolated locally, or with similar strains obtained from Europe, or re-isolated from commercial inoculants from the USA., were subjected for periods of up to more than one year to various conditions of humidity, light intensity and temperature. In all experiments carried out with strains effective on peas, vetches or clovers, the European strains were found least able, and the South African strains best able, to withstand desiccation and conditions of high light intensities combined with relatively high temperatures. All the rhizobia strains survived better in a soil rich in organic matter than in very sandy soil, river sand or vermiculite.

Physiological Studies

Nitrogen Content and Distribution. Besides problems concerning the rhizobia, various aspects of the physiology and biochemistry of legumes have been studied. For many legumes the relative development of the tops and roots and the nitrogen content and distribution in the plant at different growth stages have been determined.

Although it is impossible to generalise, it was found as a rule that the percentage nitrogen in roots, stems and petioles is relatively low except in very young organs and relatively high in the root nodules, in leaf blades, young inflorescences and seeds. The percentage nitrogen in the plant as a whole, the distribution of nitrogen and the total nitrogen content depended on genetic characteristics, the relative development of the various organs, the strain of *Rhizobium* used, the age of the organ or plant, and several environmental factors—particularly those which influenced flowering.

While various other considerations may influence the choice of a legume for a particular purpose, the total and relative development of the leaf blades, because of their relatively high percentage nitrogen, and the environmental conditions most suitable for a particular legume, should be given careful consideration in practice. The leaf/stem ratio, the root nodule/root ratio and the leaf blade/petiole ratio are also important. In several varieties of white and red clovers it was found that the petioles with not more than 1.5 per cent. nitrogen weighed up to nearly twice as much as the leaf blades which contained up to nearly 5 per cent. nitrogen. As a result, the percentage nitrogen of the leaf as a whole was usually less than 3 per cent.

Active root nodules may contain approximately 6 per cent. nitrogen, but mature roots without the nodules usually contain less than 2 per cent. nitrogen. Root systems, although normally containing the smallest percentage of the total nitrogen of a plant, may still be of value to suceeding crops, as shown in Fig. 5 with clovers, which produce relatively well-developed root systems. Oats grew well in vermiculite in which the only nitrogen present was that derived from decaying clover roots, though no nitrogen seemed to have been secreted by the clover roots during growth, as was illustrated by the fact that the oats grew no better than the controls when the clover roots had been removed.

Analyses of legumes at various growth stages and under

different climatic treatments gave interesting results. The most spectacular observation was probably the increase in dry weight and nitrogen content in many legume species after flowering had started. In the hairy vetch the dry weight as well as the total nitrogen content increased eight to ten fold after the first flowers appeared. In all species the percentage nitrogen of the whole plants decreased with age, although in young plants an increase in percentage nitrogen was sometimes registered after the seed reserves had become depleted and when the root nodules first became active.

Influence of Climatic Factors

A great deal of our research work has centred around the influence of day and night temperatures and day length on nodulation, nitrogen assimilation, growth and flowering of legumes. Experiments with a particular legume are repeated as often as possible at various times of the year in order to include the influence of changing sunlight intensity and quality with the seasons. The results differed for the species used and therefore cannot be briefly summarised, though some general statements can be made.

Day temperature. A greenhouse day temperature of 27°C as compared with a day temperature of 21°C increased the yield of such sub-tropical plants as velvet beans and peanuts, but decreased the yield and percentage nitrogen in plants such as lupins and peas, which normally grow better in autumn or spring. With other plants, for instance clovers and vetches, there was little or no consistent difference in yield or nitrogen content at the two day temperatures. In such plants the high light intensities in summer seemed to have a more detrimental effect on growth and nitrogen assimilation than the higher day temperature tested.

Night Temperature. The influence of night temperatures of 10°, 12°, 15°, 18°, 21°, and in some experiments 27°C, was investigated with plants growing at either of the two day temperatures mentioned or growing outside during the day. None of the plants tested showed a maximum yield at the lowest two night temperatures; most of them even gave higher yields at 18° than at 15°C. Some legumes, such as velvet beans and peanuts, grew best at the still higher night temperatures. Other plants (peas, for example) grew equally well over a fairly wide range of night temperatures and, within limits, showed no marked optimum temperature. The higher night temperatures increased the percentage nitrogen in sub-tropical legumes and even in peas, but had little influence on the percentage nitrogen in species of clovers, lupins and vetches. Flowering was usually accelerated at higher night temperatures.

Day length. A day length of 16 hours stimulated the flowering of the varieties of clovers and vetches tested, inhibited the flowering of *Vigna parviflora*, varieties of soybean and most *Crotalarias*, or had only a slightly quantitative, if any, effect on the flowering of pea, broad bean, lupin and peanut varieties used. Typical examples of hairy vetch plants in short and long days are illustrated in Fig. 6.

The shoots of some plants kept for several months in short days were marked with white wool just behind the growing points and these plants were then transferred to long days. The younger shoots elongated rapidly and inflorescences visible to the naked eye developed within three weeks. When similar plants kept in short days were sprayed with gibberellic acid they grew more rapidly and became taller than in long days. The first microscopic indications of inflorescences appeared after nearly six weeks.

In comparison with a 12-hour day, a day length of 16 hours had little influence on the yield of the day neutral plants, but significantly increased the yield of the long day as well as the short day plants tested. The longer days generally depressed the percentage nitrogen of plants but had no significant influence on the percentage nitrogen of peanuts and velvet beans and actually increased the nitrogen in *Vigna parviflora.*

Long days had a striking effect on the size and shape of nodules of clovers and vetches. They were much larger and more branched than in the shorter days. Nevertheless, the size of the nodules did not necessarily indicate a noticeably enhanced nitrogen assimilation under these conditions.

Biochemical Studies

Problems of a specifically biochemical nature which have been investigated have been concerned mainly with the amino acid composition and metabolism of legumes: some novel amino or imino acids have been isolated and identified.

A labile compound closely related to homoserine was detected in relatively large quantities in the free amino acid extracts of immature pea fruits by paper chromatography. This compound was conclusively shown to be the O-acetyl derivative of homoserine which has apparently never been found in plants before.

Bean plants are known to contain substantial amounts of pipecolic acid in their seeds; but this imino acid can hardly be detected in the vegetative parts of normal bean plants. In human organisms and fungi, pipecolic acid appears to be an end-product of metabolism.

Studies were undertaken to see whether bean plants can metabolise pipecolic acid. The results indicate that the plants can metabolise the imino acid to a large extent despite the fact that these plants, when supplied with pipecolic acid as the sole source of fixed nitrogen, showed severe symptoms of nitrogen deficiency.

The influence of nitrogen nutrition on the amino acid composition of peas has been studied. Plants were fertilised with different nitrogen compounds and their composition compared with plants solely dependent on rhizobia for their nitrogen requirements. The most striking effect of nutrition found was that plants fed on urea contained a higher concentration of amino acids or amides, particularly arginine and homoserine, than the plants inoculated with rhizobia.

A more detailed review of the work summarised in this article can be found in the *Annual Report* of the Plant Physiological Research Institute, University of Pretoria, which is published at the beginning of each year.

Nitrogen Fixation by Non-Legumes

by **Greta Stevenson,** Ph.D., *Nuffield Research Fellow, University of Wellington, New Zealand.*

The problem of soil fertility is one of the most complex with which agricultural scientists grapple, for the earth, the basis of man's life, proves on analysis to be an enormously complicated mixture of compounds and organisms. Since the earliest times men have learnt by empirical methods how to use and improve the soil, but in this age we strive to understand these processes in scientific terms so that better use and further improvements may be made.

Of all the elements which occur in soil the one which plants take up in greatest amount is nitrogen, but this is available only in its mineral forms, which are present in small amount and which may be quickly exhausted. The supply of available nitrogen is often a limiting factor for crop growth and manurial practice consists mainly of adding or replacing soil nitrogen. In places such as the pasture lands of New Zealand, where the only economic fertiliser practice is the adding of superphosphate, which supplies both phosphorus and sulphur to plants, the main result is still to increase soil nitrogen by stimulating clover growth and ultimately providing more food for animals. Manures or fertilisers containing nitrogen are expensive, especially in lands distant from centres of manufacture, so that often they cannot be used even on fields where their addition would substantially increase yield. A clear understanding of the balance between plant and soil nitrogen is obviously of basic importance, yet it is clear from published data that many fundamental problems in this connection remain unsolved.

During the nineteenth century the question of the nitrogen nutrition of higher plants was subjected to close investigation by many workers, most notably those pioneers of Rothamsted, Lawes and Gilbert. They began before 1860, by carefully assembling data from field experiments which showed that with the growth of leguminous crops and turnips which received mineral non-nitrogenous manures, there were large, unexplained gains in nitrogen. Rigid pot experiments designed to show whether green plants could use nitrogen from the air failed, however, and Lawes and Gilbert concluded in their earliest publication on this topic that green plants could not use the atmospheric nitrogen. The subject was widely discussed. The great German chemist, Liebig, who disputed the theories advanced by Lawes and Gilbert, had stated as early as 1847, 'That the nitrogen of wild plants must be derived from the air is so obvious that it requires neither proof nor experiment'—a rather sweeping claim to come from the critic who also said later (1863) that Lawes and Gilbert 'have not the slightest notion of what is meant by argument or proof'.

Work continued. Following the discoveries of Pasteur there was an appreciation of the activity of micro-organisms, including those in the soil which converted nitrogenous organic residues to mineral and gaseous nitrogen. Finally, by 1890, Hellriegel and Willfarth had established that nitrogen fixation took place in clover nodules, so the gains in nitrogen found with the growth of leguminous crops were explained and the conclusion was widely accepted that no other higher chlorophyllous plants could directly assimilate free nitrogen.

Recent Investigations

For many years the problem lay fallow. More recently there has been renewed interest in the subject and a modern review by Allison points out that there still is a problem. Puzzling discrepancies have been found in many records of crop growth and yield with respect to the balance between nitrogen removed in the crop and accumulated in the plants on the one hand, and nitrogen remaining in the soil and supplied as fertiliser on the other hand. In orchards of various different kinds of trees, in experimental plots kept under continuous wheat for long periods, and also in land under other crops such as

An aerial view of a 14,000 acre sand reclamation scheme in New Zealand.

Photo : New Zealand National Publicity Department.

rape and turnips, careful measurements have shown a gain in nitrogen which cannot be explained by current theories.

When we turn to uncultivated land the problem of where the plants obtain their supplies of nitrogen is more acute. Original mineral soil or depleted land may contain little or no nitrogen; yet, after the growth of many kinds of non-leguminous plants in such a medium, a large amount of organic matter containing nitrogen is built up. Records from many different parts of the world are available, showing a steady increase in soil nitrogen with undisturbed natural vegetation of grasses or trees, in which legumes play no part.

In New Zealand the rapid growth of exotic pines on depleted mountain country and even on sand dunes is striking. Measurements made by the writer show that in these pine forests over periods of 25 years there has been an annual gain in nitrogen of 30-40 lb. per acre. This figure is of the same order as that given for accumulation of soil nitrogen in other places left under natural vegetation. Such an increment to the soil with the growth of higher plants is in addition to all other known gains or losses of soil nitrogen, the factors governing which are discussed below.

Sources of Nitrogen

The most obvious addition comes with ammonia or nitrate washed down in rain. In the neighbourhood of big industrial centres and in some tropical places with high rainfall the amount may reach 10 lb. N per acre per annum, but recent careful measurements in Australia gave a figure for certain wheat-growing districts of under 1 lb. N per acre per annum. The only other factor known to add nitrogen to soil is the growth and activity of non-symbiotic nitrogen-fixing micro-organisms which live in the soil and use nitrogen from the air to build up nitrogen compounds. Many of these organisms grow readily in sugar solutions in the laboratory but their activity in soil is another matter. Normally they are present only in fertile cultivated soils where the turnover of nitrogen is rapid and considerable; they are generally absent from infertile natural soils. They may be credited in the places where they do occur with an addition of 1-5 lb. N per acre per annum.

Against the gain of nitrogen from these causes we have to weigh the loss in drainage water and the loss by denitrification. Drainage water generally carries away more nitrogen than is added by rain, and during flood time there may be high loss of organic matter. Denitrification is a process by which nitrogen compounds in the soil are reduced to gaseous nitrogen which escapes to the air. This process is extremely active in highly fertilised soil where as much as 60 per cent. of added fertiliser nitrogen may be lost to the air in the space of three months, only 30 per cent. being left for the plants. Such enormous losses represent a serious wastage in highly cultivated land. Similar losses, necessarily on a smaller scale, occur from all other kinds of soil where denitrifying bacteria are widely distributed.

Thus when a balance is made of all the losses and gains which have been measured, both for some cultivated soils and for other soils under natural conditions, we find that there is an annual gain in nitrogen of the order of 50 lb. per acre per annum with the growth of a variety of non-leguminous plants. The only possible source appears to be the atmosphere; therefore it is considered likely that many plants beyond those at present known to be capable of the process, do, in fact, carry out fixation of nitrogen.

'No-Nitrogen' Pot Trials

A number of plants which have been observed to grow well in New Zealand on soils very poor in nitrogen have been selected for experiment and grown in pots in a

strictly non-nitrogen culture. *Coprosma robusta*, a shrub belonging to the coffee family, *Nothofagus fusca*, a southern beech tree, *Aristotelia serrata* and *Leptospermum scoparium*, shrubs of the families Elaeocarpaceae and Myrtaceae respectively, and *Epilobium erectum*, a weed—all native plants of New Zealand—have been tried along with the exotic species, *Pinus radiata*, *Raphanus sativus*, cultivated radish and *Dactylis glomerata*, cocksfoot grass. The experiments were started with seedlings which had already developed their natural mycorrhiza, or in the case of the grass and the radish with unsterilised seed.

The only one of these plants which grew well in pot culture over a long period (three years) was *Pinus radiata*, but all grew well for the first six months, at least, and some continued, more slowly, for another six months. In all cases there was a substantial gain in nitrogen, and, as other possibilities were ruled out it was presumed that some nitrogen fixation process had taken place with the growth of these higher plants.

As the use of isotopic nitrogen offered a method for exact testing of the nitrogen fixing ability of these plants, a number of experiments with labelled gas have been carried out. Plants have been grown in the strictly non-nitrogen culture in sand watered with culture solution, in enclosed glass pots to which has been added an atmosphere containing labelled nitrogen gas. After a period of growth the plants have been reaped, the combined nitrogen extracted from the plant substance and returned to the mass spectrometer for detection of the heavy isotope, 15N. Positive results with this technique have proved *Pinus radiata*, *Coprosma robusta*, *Nothofagus fusca*, *Raphanus sativus*, *Epilobium erectum* and *Dactylis glomerata* all to have utilised gaseous nitrogen. Further tests with detached shoots of *C. robusta* and also of *Prunus armeniaca*, cultivated apricot, have shown nitrogen fixation to occur in the leafy parts of these plants.

These results are in accordance with the field evidence which so strongly suggests that nitrogen fixation on a considerable scale takes place during the growth of many plants without root nodules. What mechanisms are involved we do not yet know, and much more work will be required to tell the full story. In the case of the trees and the grasses it is possible, even probable, that the nitrogen fixation is due to the activity of the mycorrhizae (fungus roots) which these plants commonly have. The leafy shoots which have been tested have stipular or leaf glands similar to those of many shrubs and trees which flourish in poor soil, and the possibility that these are nitrogen fixing organs must be investigated. Much careful work with pure cultures and combined cultures of higher plants and known micro-organisms will be necessary, but at least from the results obtained so far we can see the problem a little more clearly. When we have better information about how the trees and grasses use nitrogen from the air we can expect to find out how to favour the process for the benefit of forestry and agriculture.

Pinus radiata, *25 years old, growing on sand in New Zealand. During the life of these trees there has been an annual gain in nitrogen of 30-40 lb. per acre.*

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CMPP for Cereal Weed Control

by **F. R. Stovell,** *Shell Chemical Company.*

One of the major weed problems in winter cereals on heavy land in the United Kingdom, and to a varying extent in a number of European countries, is cleavers, *Galium aparine*. With the introduction of growth regulating weedkillers and their widespread acceptance by the farmer this weed has suffered from less competition and has spread widely as a result. For similar reasons, chickweed, *Stellaria media*, has increased its hold in cereal crops.

In the early days of weed control, DNOC and sulphuric acid both dealt with these weeds selectively and kept down their numbers, but MCPA and 2-4,D give no control of cleavers and only a check of chickweed. This change in weedkilling technique, coupled with combine harvesting methods, has increased the problem in spring-sown as well as autumn-sown cereals. Apart from competing for soil nutrients, dense growths of cleavers pull down the crop, causing lodging and making harvesting difficult, often almost impossible. Further, the seeds are much of a size with wheat grains rendering cleaning more difficult and facilitating the propagation of the weed in seed corn.

The poisonous properties of DNOC, even more than its dependence on weather conditions for a satisfactory control of cleavers, has led to much effort being used to discover a non-toxic material which could be substituted for it. The material which has now been widely accepted as the answer to this problem was first recorded in a paper by Fawcett, Osborne & Wain in 1953 (1) and mentioned further by Fawcett, Wain & Wightman in 1955 (2). It was shown then that among other substituted phenoxy acetic acids MCPP, α(2-methyl 4-chlorophenoxy) propionic acid, showed considerable growth regulating activity. It was left, however, to Lush (4) and Leafe (3) to discover that this material did give a control of cleavers. In the laboratory at Wye, Professor Wain's team had shown this material to have very similar activity as a growth substance to MCPA, and it was concluded by these workers that the basic activity of these compounds is probably the same. As yet, no reason can be given for the different selectivity of CMPP and MCPA. It may well be that there is some mechanism within the cleaver which prevents movement of MCPA which does not prevent movement of CMPP. This seems the most likely explanation since the difference in activity does not appear to occur at cell level.

It may be interesting to recall at this stage that during the years before the development of CMPP there were occasional reports received of cleavers being controlled by MCPA. These were always isolated incidents and could never be repeated, though the evidence for each incident was plain. CMPP is produced as a mixture of the dextro- and laevo-rotatory forms of α(2-methyl 4-chlorophenoxy) propionic acid. Only the dextro-rotatory isomer is herbicidally active, but it is not economically feasible to separate the two forms. Accordingly, whenever dosage rates of the material are referred to, acid equivalents are given for the mixed dextro- and laevo-isomers. The material is generally formulated either as an amine or a metallic salt, and contains 3 lb. of active acid per gallon. Of the metallic salts the potassium salt is remarkable because of its particularly high solubility. The solubility is such that a solution of the potassium salt may be prepared which contains 48 per cent wt. volume of the free acid, and this solution may be maintained at a temperature as low as —8°C. without the deposition of crystalline material. Under certain circumstances this solution may solidify as a solid solution with no deposition of crystalline salt occurring, the solid melting as the temperature rises. Formulation of the product must naturally take care of any salts which are likely to occur in the water used for spraying, but otherwise presents little difficulty. There is no significant difference in activity between the metallic and the amine salts.

Limitations

Despite its relatively recent discovery CMPP, which has been given the standard name, mecoprop, has been very widely used in the United Kingdom, this use being confined to cereals and grasses being grown for seed. The material is toxic to clover and so must not be used on undersown crops; nor, since its persistence in the soil is similar to that of MCPA, should it be used on cereals which are to be undersown in the year of spraying. There has been confusion over this last point in the minds of some farmers who consider that as the material controls the same weeds as DNOC and Dinoseb, it may be used in the same way, before undersowing. This, of course, is not so.

The material is rather safer to use on cereals than MCPA and can be applied from the two-leaf stage onwards in the case of barley and oats. With wheat the position is not quite so clear since early application may cause distortion, particularly in the varieties Atle and Atson. It is interesting to note, however, that the variety Koga II, which has achieved considerable popularity with farmers, is non-susceptible to CMPP and may be sprayed from the two-leaf stage onwards. From work done at present it

seems that the deformities produced in spring wheats from early application do not affect the yield, and crops which are not to be taken for seed may, therefore, be treated if the farmer realises that deformities may result. For all crops of wheat to be taken for seed apart from Koga II, application should be delayed until the five-leaf stage.

The spectrum of weeds controlled by CMPP is practically the same as that for MCPA, but with the notable difference that chickweed is exceptionally well controlled, cleavers controlled and a very useful control obtained of campions, *Melandrium* spp. The accompanying table gives the reaction of various weeds to CMPP.

It has been found that the growth response curve of CMPP is very much steeper than that for MCPA. This means that small increases in the dosage rate which would not be expected to produce noticeable differences in control in the case of MCPA, frequently produce marked differences in response with CMPP. Generally speaking the application rate is for 6 pints of product containing 3lb. to the gallon per acre. However, the control of chickweed is so effective that under good growing conditions this dosage rate may be reduced to 4 pints per acre.

Temperature Effect

The effect of temperature on CMPP appears to be much more marked than on MCPA. This may be due to growth conditions affecting the plant more than temperature conditions at the time of spraying, but where plants have been exposed to low temperature conditions, the dosage rate should be increased to 8 pints per acre. This is particularly noticeable in the case of cleavers. The importance of the average overall temperature being the criterion is underlined by last year's experience in the United Kingdom where a series of bright sunny days seemed to indicate ideal spraying weather, yet at the same time there were sharp frosts every night so that the soil temperature did not rise greatly. Under these conditions plant growth was retarded and where the standard rate was used results were not so good as those obtained with the increased dosage.

Another weed which should receive special attention is redshank, *Polygonum persicaria*. Under some conditions CMPP at the standard rate has given a better control than MCPA when sprayed at an early stage of growth. On other occasions, however, under apparently similar conditions the reverse has been true, and it would appear from a study of these results that where conditions favoured repeated growth CMPP might give the more effective control of this weed, the differential effect being reduced till, under unfavourable growing conditions, it is reversed, but it is impossible to be dogmatic about this at this stage.

It was hoped when CMPP was introduced that it would also provide an answer for the control of mayweed. In the event it has been shown not to control stinking mayweed, *Anthemis cotula*, but to be quite effective in the control of scentless mayweed, *Matricaria maritima*, v. *inodora*. An interesting comparison between CMPP and MCPA is in the difference in response observed between fat hen, *Chenopodium album*, and orache, *Atriplex patula*, which are often confused by farmers. Fat hen can be satisfactorily controlled at dosages down to 4 pints per acre, while orache is moderately resistant to this rate and requires the full 6 pints.

Conversely, there is very much less difference between curled dock, *Rumex crispus*, and broad-leaved dock, *Rumex obtusifolius*, in their response to CMPP than there is in their resistance to MCPA, to which broad-leaved dock, except in the seedling stage, is to all intents and purposes resistant.

As may be expected with such a new material, there are still several avenues being explored which may provide additional uses for it. So far one of the most successful has been autumn application of the material to control chickweed, and indeed the control of chickweed at all times of the year with CMPP makes it a very valuable contribution to the number of chemicals at the farmer's disposal for weed control. Where grasses are being established for seed production, trouble is often experienced in the young stages and CMPP can be applied effectively for the control of weeds from the two-leaf stage of grass onwards. It is particularly useful in crops of cocksfoot for this purpose, and reports have also been received of its use on rhubarb at the scale stage—i.e., before the shoots have emerged from the ground—for the control of winter weeds.

The control of speedwells, *Veronica* spp., varies but under some conditions a much better response than that obtained with MCPA can result from the use of CMPP. Frequently a mat of speedwell will occur in lawn grasses and can be eradicated by the use of this material. At the the same time there will be some yellowing of the grass, but this is short lived and the turf regains its natural appearance.

There is one marked difference in the application of CMPP: it appears to respond much more than MCPA to increases in the amount of water in which it is applied. While good results can be obtained with MCPA at 10 gal., CMPP should never be applied in less than 20 gal. of water per acre and improved control is sometimes seen as the rate is increased up to 50 gal. per acre. The increased efficiency with increased volume appears to be tied up with the need for penetrating the crop cover to give an overall cover of weeds. It is particularly valuable in the case of chickweed, but the results are less noticeable with cleavers where these are growing up the crop. As stated earlier, CMPP has only recently been introduced and work is still continuing to discover its full potentialities. In the meantime it can confidently be recommended as an excellent material for the control of cleavers and chickweed and some of the other weeds not readily controlled by MCPA and 2-4.D.

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A crop of barley dragged down by cleavers, Galium aparine.

This picture shows typical growth suppression of cleavers, Galium aparine, *resulting from the application of CMPP at 6 pints per acre.*

Samples of cleavers, Galium aparine, *sprayed at different rates with CMPP (3 lb. per gal.)*
Left to right: *2 pints per acre; 4 pints per acre; 6 pints per acre.*

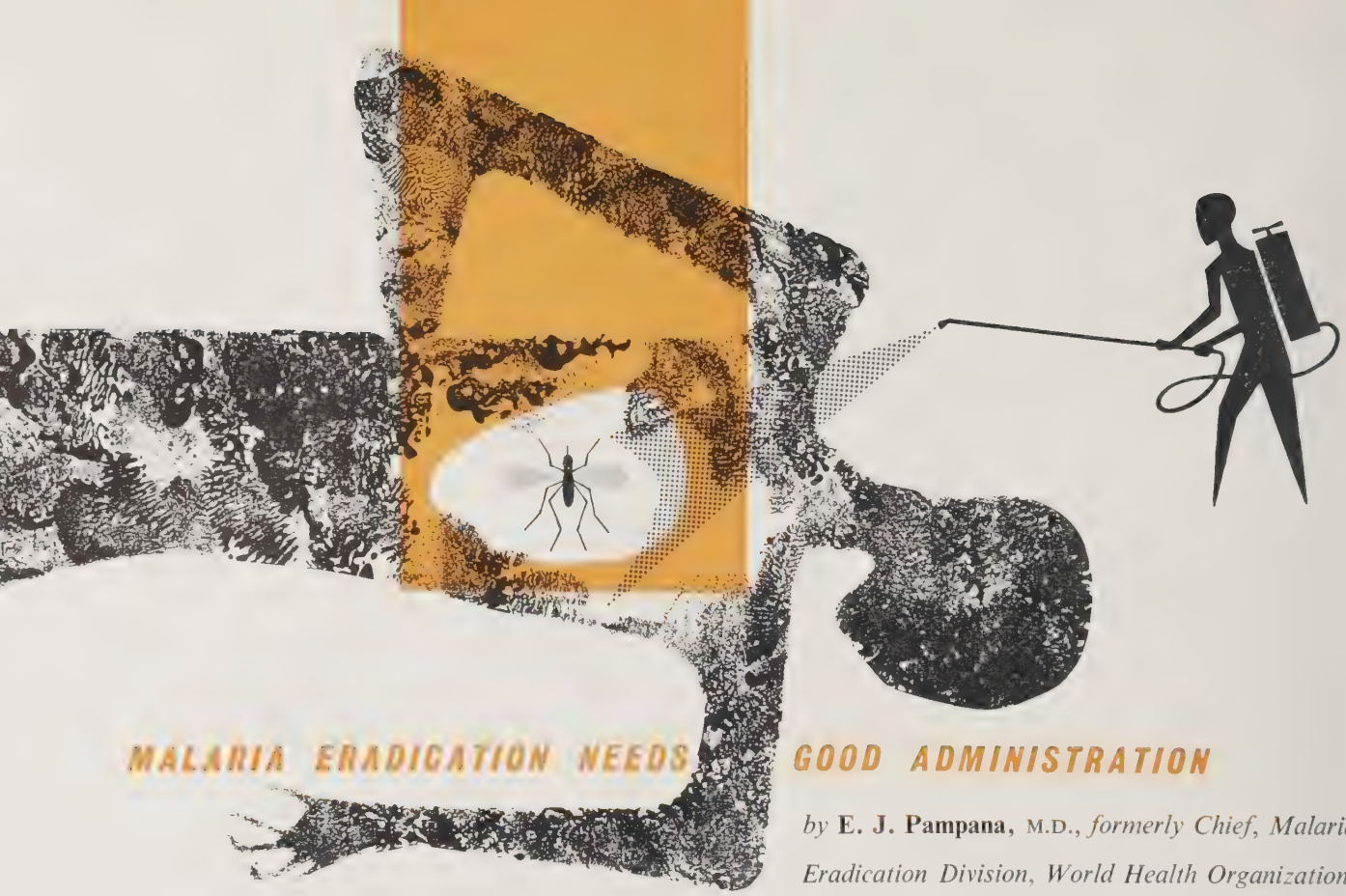
Table
(Adapted from a table in *Weed Control Handbook*)

The response of annual weeds and seedling biennials and perennials to MCPA and mecoprop (CMPP).

Weed Dose: oz. acid equiv. per acre		*MCPA (salt)*[1] 12	24	*Mecoprop (salt)* 24[2]	40[2]
1. *Anagallis arvensis*	Sd	MR	MS	R	
(scarlet pimpernel)	Yp	R	MR	R	
2. *Anthemis cotula*	Sd	R	MR	R	
(stinking mayweed)	Yp	R	R	R	
3. *Atriplex patula*	Sd	MS	MS	MR	S
(common orache)	Yp	MR	MS	MR	S
4. *Brassica nigra*	Sd	S	S	S	S
(black mustard)	Yp	S	S	S	S
5. *Capsella bursa-pastoris*	Sd	S	S	MS	S
(shepherd's purse)	Yp	MS	S	MS	S
6. *Chenopodium album*	Sd	S	S	—	S
(fat hen)	Yp	S	S	—	S
7. *Chrysanthemum segetum*	Sd	R		R	
(corn marigold)	Yp	R		R	
8. *Fumaria officinalis*	Sd	MS	S	MS	S
(fumitory)	Yp	R	MR	MS	S
9. *Galeopsis tetrahit*	Sd	MS	S	R	MS
(hempnettle)	Yp	MR	MS	R	MR
10. *Galium aparine*	Sd	R		MS	S
(cleavers)	Yp	R		MS	S
11. *Lamium amplexicaule*	Sd	MR	MS	R	
(henbit)	Yp	R	R	R	
12. *Lamium purpureum*		MR		R	
(red deadnettle)		MR		R	
13. *Matricaria maritima*	Sd	R	MR	R	MS
ssp. inodora	Yp	R	R	R	MR
(scentless mayweed)					
14. *Melandrium album*		R		MR	
(white campion)		R		MR	
15. *Papaver rhoeas*	Sd	MS	S	S	S
(corn poppy)	Yp	MR	MS	MR	MS
16. *Polygonum aviculare*	Sd	R	MR	R	MR
(knotgrass)	Yp	R	R	R	R
17. *Polygonum convolvulus*	Sd	R	MR	R	MR
(black bindweed)	Yp	R	R	R	R
18. *Polygonum lapathifolium*	Sd	R	MR	MR	
(pale persicaria)	Yp	R	R	MR	
19. *Polygonum persicaria*	Sd	R	MR	R	MR
(redshank)	Yp	R	R	R	R
20. *Ranunculus arvensis*	Sd	S	S		S
(corn buttercup)	Yp	MS	S		MS
21. *Raphanus raphanistrum*	Sd	S	S		S
(wild radish)	Yp	MS	S		S
22. *Rumex crispus*	Sd	S	S		S
(curled dock)	Yp	MR	MS		S
23. *Rumex obtusifolius*	Sd	S	S		S
(broad-leaved dock)	Yp	MS	S		S
24. *Senecio vulgaris*	Sd	MR	MS	R	MR
(groundsel)	Yp	R	R	R	R
25. *Sinapis alba*	Sd	S	S		S
(white mustard)	Yp	S	S		S
26. *Sinapis arvensis*	Sd	S	S		S
(charlock)	Yp	S	S		S
27. *Sonchus oleraceus*	Sd	MS	S	R	MR
(annual sowthistle)	Yp	MR	MS	R	R
28. *Spergula arvensis*	Sd	MR	MS	R	MR
(corn spurrey)	Yp	R	R	R	R
29. *Stellaria media*	Sd	MR	MS	S	S
(chickweed)	Yp	R	R	MS	S
30. *Urtica urens*	Sd	MS	S		S
(annual nettle)	Yp	MR	MS		S
31. *Veronica agrestis*	Sd	MR	MS	MR	
(procumbent speedwell)	Yp	R	R	MR	
32. *Vicia sativa*	Sd	MS			S
(common vetch)	Yp	MS			S
33. *Viola arvensis*	Sd	MR	MS	R	
(field pansy)	Yp	R	R	R	
34. *Viola tricolor*	Sd	MS	S	R	
(heart's ease)	Yp	R	MR	R	

[1]Sodium, potassium or amine.
[2]Total mecoprop (CMPP) in terms of active and inactive isomers in ratio 50/50.

Sd=seedling; Yp=young plant; R=resistant (no useful effect); MR=moderately resistant (temporary suppression); S=susceptible (complete or near-complete kill); MS=moderately susceptible (effective suppression).



MALARIA ERADICATION NEEDS GOOD ADMINISTRATION

by **E. J. Pampana,** M.D., *formerly Chief, Malaria Eradication Division, World Health Organization.*

Malaria eradication, as understood today, does not mean eradication of the malaria vectors: it means eradication of the malaria parasites from the population in a given area. It has become practically feasible thanks to house-spraying with residual insecticides (DDT, BHC or dieldrin being the three generally used). If the inside walls of all dwellings of a large area are covered with adequate particles of insecticide, vectors that come indoors to transmit the infection are killed; transmission is thereby interrupted and no new cases of infection occur. If this absence of transmission is maintained for a minimum period of three years, it can be assumed that the great majority of old malaria cases will no longer have malaria parasites capable of infecting the mosquitos—and the few individuals that still have them can easily be treated individually. Anti-mosquito activities can then be discontinued, provided that adequate safeguards are taken to prevent re-establishment of transmission.

To keep all the inside walls of all the dwellings of a malarious country continuously covered with insecticide particles during the transmission periods of four consecutive years (in many tropical countries this would mean every day of the four years) would be a tremendous undertaking, even if only one or two sprayings a year were adequate. It is like keeping an army in the field, or taking a detailed census twice a year (with the difference that in a census it is not necessary to spray all the walls, and if a few families escape its purpose is not fully defeated, while in malaria eradication it is).

Obviously such a tremendous undertaking requires a precise plan of operations. Generally a malaria eradication programme involves a year of preparation, four years of "total coverage" spraying (phase of attack) followed by three years of consolidation—i.e. detecting possible parasite carriers and preventing the danger they would represent of re-establishing transmission. If at the end of this period it can be ascertained that malaria has been eradicated then a maintenance phase follows; this does not need a special malaria service. The plan of operations must define the action to be taken in each locality of the country for every month, or even for every week, of most of the eight years.

Malaria eradication, obviously, is a serious responsibility for any government to undertake. It must be recognised that every country has its own pattern of administrative procedures which it is difficult to alter. Even in this 'atomic' age there are government administrations which still do not approve of typewritten documents for certain categories of official papers! Administrative patterns often do not keep pace with modern methods and requirements and may well be unsuitable for the needs of an eradication programme. The World Health Organization Expert Committee on Malaria (1) has strongly advised that such a major enterprise should be entrusted to a national

Adequate mapping of malaria eradication areas is an essential part of the administration of a programme; this photograph from the Philippines illustrates types of maps which may be used.

malaria eradication service (NMES) which should be a primary branch of the ministry of health, have a large measure of authority and autonomy, and which might typically consist of three main departments—epidemiology and evaluation, operations, and administration.

Administration Defined

Administration has been defined (2) as the sum of activities established with a view to achieving a particular objective. Hence administration is necessary for any kind of programme, public health included. It would therefore appear superfluous to write this article. But reason and experience show that in the case of malaria eradication administrative efficiency of a very high order is a *sine qua non*. This is not the case for most other public health programmes such as BCG vaccination or environmental sanitation, or even malaria control. A malaria control project, if poorly organised and administered, may begin behind schedule, or protect only a fraction of the population it was planned to protect, but it would still save a number of lives and prevent a great deal of sickness and would therefore be at least a partial achievement. In malaria eradication there is no such thing as a partial success. Any progress short of keeping transmission to the zero level is failure.

The 'total coverage', the correctness in quality and time of the spraying operations, is the responsibility of the operational department of the NMES, provided it has available, at the times and places established in the plan, the necessary personnel, transport, equipment and supplies. It will depend on the administration for these services. Excuses such as, for instance, that motor vehicles imported from abroad are not available at the right time because they have been delayed by the customs cannot be allowed. Nor should it ever have to be admitted that operations were interrupted or delayed because the personnel were so underpaid that they could not be maintained in the job; nor that supervision failed because there was no suitable transport for the supervisors. Events of such a kind are unfortunately very frequent and they all lead to a same result: the schedule of the plan cannot be fulfilled and the whole programme may need to be prolonged for a year or more, with great increase of cost and greater danger of the appearance of insecticide-resistance in the vectors.

Another definition of administration is 'the performance and management of affairs' (3). The responsibility of the administrative department of a NMES would then be that of implementing and managing the non-technical aspects of the programme. We must be careful not to accuse the administration for failures over which it has no control: the department cannot have an authority exceeding that of the organisation to which it belongs. If it is found, for example, in carrying out the programme, that the

Efficient transport arrangements play an important part in malaria eradication programmes; this photograph was taken in the Philippines.

Treasury does not put the necessary funds at the disposal of the NMES when they are required, the NMES administration can hardly force the payment of these funds, unless the Treasury has formally made the relevant commitments. Hence, the administrative basis of a programme must be firmly laid before the administrative body if the NMES is to start work.

It is during the preparatory phase that the conditions for a sound administration are laid. The country (i.e. the government and the legislature), the medical profession and the leaders of public opinion should be convinced that malaria eradication is a 'must' for the country. They should look upon it as 'an urgent measure outside the regular routine of the health department' (4)—urgent, therefore, and exceptional, and justifying exceptional and urgent measures. Suitable legislation and official regulations must be prepared and passed before operations start. They must provide for the establishment of an adequately organised NMES; for the establishment of a budget covering the programme as a whole, even if allocations will have to be voted annually; for the indispensable co-operation of the relevant government departments with the NMES; and for the creation of a high-level interdepartmental council for malaria eradication. A clause should be inserted to the effect that further adjustments may prove necessary according to experience. If it is recognised that existing regulations offer unattractive salaries and conditions of work for NMES workers and that the NMES would have no authority to modify them, new regulations must be issued to enable more adequately paid posts to be offered with security of tenure for the duration of the programme, and possibly to provide for the transfer of the employees to other work when the programme is over. If it is clear that existing procedures would delay action as regards payment of salaries, waiving of customs restrictions, and so on, it will be essential to issue new regulations enabling the NMES to short-circuit such procedures.

It should be emphasised that all these provisions must be sanctioned before operations begin. If they are not in force by then, even the most efficient administration of any NMES will fail. One cannot help feeling that the director of the service would be justified in delaying the start of the attack phase until efficient top-level backing of the programme has materialised, with the approval of adequate legislation and official regulations.

Technically Trained Administrators

Where such backing exists, the NMES will function with authority. Its administration will be the auxiliary of the other departments of the service and its task will be that of meeting their needs (5). To this end it is highly desirable that the administrators be thoroughly trained in malaria eradication so that they can understand not only the aims,

A team is briefed before setting out on a spraying operation in Tanganyika.

but also the techniques of operation and the evaluation of the programme. Only if they are fully aware of their meaning will they be able to consider the needs of the other departments and give intelligent co-operation. It is assumed, of course, that the internal regulations of the service will have clearly defined the responsibilities of each department so that there is no ambiguity.

Duties

The administration will always have the following responsibilities:—

(i) To ensure that funds are available in time to fulfil the targets of the plan and to meet emergencies, such as the development of resistance by a vector to the insecticide; its replacement by another may be quite expensive, but the administration must supply it in time—assuming, of course, that emergencies of this kind had been envisaged in the plan of eradication;

(ii) To establish personnel posts as required by the various phases of the programme and to ensure that personnel can be recruited at the appropriate time, making provision for their payment, lodging and transport;

(iii) To order the necessary transport, equipment and supplies and provide for their dispatch to the various localities according to the plan; to set up and manage appropriate stores and to ensure that the material will be immediately available to the two departments when and where required;

(iv) To carry out the accounting and the control of expenditures using technological means and procedures appropriate for the size of the task;

(v) To find ways and means of solving unforeseen administrative problems, and therefore not provided for in the new law or regulations.

It may be concluded that for the success of any malaria eradication plan sound administration is essential. Its basis must be laid and sanctioned before the end of the preparatory phase, so that when the phase of attack begins the administrative department of the national malaria eradication service can give the necessary services and support, without any delay, to the operations and evaluation departments. Without such efficient and timely services and support the programme may be seriously jeopardised, its duration prolonged, and its result may even be failure.

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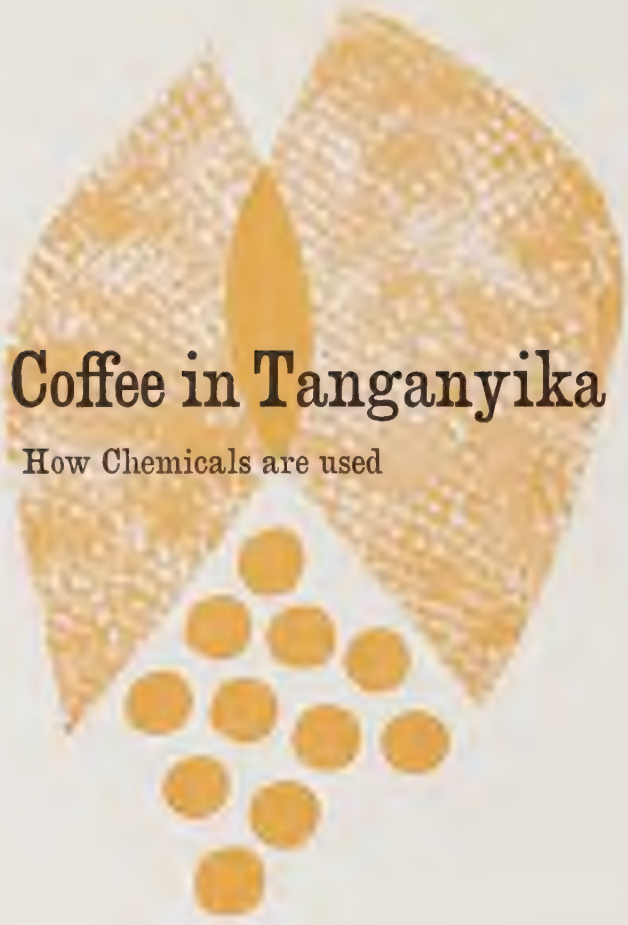


Coffee in Tanganyika

How Chemicals are used

by **H. Sandford,** *Shell Chemical Company. Formerly Agricultural Officer, H.M. Overseas Service.*

On the slopes of Kilimanjaro, Africa's highest mountain, and on Mount Meru, situated nearby, Tanganyika is fortunate in having a prosperous and thriving coffee industry. Smaller areas of *Coffea arabica* are also grown on Mount Oldeani and in the Southern Highlands. European and Asian plantations are situated at the lower elevations up to about 4,500ft., and these are generally big concerns of several hundred acres employing large numbers of native labourers and having their own factories. Above these estates, up to an altitude of about 6,000ft., the land is owned by Africans under a highly complicated system of land tenure and they have planted coffee in small plots each of about half an acre. The largest of the tribes, the Wachagga, are organised into a highly efficient society known as the Kilimanjaro Native Co-operative Union, which is responsible for all the agricultural, processing and marketing aspects of production.

East African arabica coffee is well known throughout the world for its excellent liquoring qualities and its fine aroma, and it is used extensively for blending with lower quality coffees. For some years the price has been very high with the result that European, Asian and African planters alike have prospered exceedingly. This, together with the knowledge of improved cultural practices (most of which have originated from the Coffee Research Station, Lyamungu, situated on Kilimanjaro itself), has meant that increasing use is being made of a wide range of agricultural chemicals. Even the usually backward natives, amongst whom the Wachagga must be regarded as one of the most enlightened tribes in Africa, have not been slow to take advantage of some of these chemicals, particularly in the control of pests such as antestia and white stem borer. Much of the credit for their remarkable progress is due to the agricultural instructors, many of whom have been educated at the coffee school run by the Union for the benefit of its members.

Fertilisers

The predominant soil type in the main coffee-growing areas is a very fertile, red, volcanic loam of considerable depth and good texture. On some of the small African holdings, in particular, coffee has been planted on very steep slopes, little or no attempt being made to prevent erosion. This is further aggravated by irrigation from an extensive system of streams and watercourses which run down the mountain, and also by the torrential rains which fall during April and May. Much is being done to encourage soil conservation measures, such as the construction of contour bunds and mulching with banana trash, but a great deal still remains to be done to prevent the enormous losses of fertile topsoil.

In view of this, it is perhaps a little surprising that inorganic fertilisers have seldom given significant increases in yield, even on old land which may have been cropped for many years without the nutrients lost by the removal of the crop being made good. The soils are of course very fertile, being particularly well supplied with bases; another possible explanation is that the coffee has such a very extensive root system that the applications of fertilisers have been inadequate to show a response.

In an experiment at the Coffee Research Station the annual application of 6oz. sulphate of ammonia per tree (equivalent to approximately 40lb. N per acre) did not give a consistently significant increase in yield. It is possible that larger dressings would have given better results but most of the soils are so inherently fertile anyway that it is doubtful whether any slight yield increases obtained would be economically worth while.

There are occasions, however, when the application of nitrogen would undoubtedly be beneficial, and this applies particularly to young coffee, which should be given a good start in life if it is to yield well in later years. In the nursery, nitrogen dressings combined with irrigation keep the plants growing actively during dry weather and planting out in the field can take place earlier than would otherwise have been possible. Transplants require very careful treatment with liberal manuring, preferably with well rotted compost or manure and occasional top dressings of nitrogen to stimulate growth. Coffee is normally planted 9ft.×9ft., giving a population of 540 plants per acre, but experiments are now being undertaken at higher

densities of up to 2,940 plants per acre; if such spacing systems are successful and are adopted in general practice, correspondingly greater amounts of manures and nitrogenous fertilisers will be required.

Mature trees, defoliated as a result of leaf rust or debilitated for any other reason, should be given a dressing of nitrogen and irrigated during dry weather; this will bring out a fresh flush of leaf.

Banana trash applied as a surface mulch between the rows is regarded as an ideal manure for coffee and generally gives large increases in yield. Bananas respond well to nitrogen and it is possible that it would be better to apply the fertiliser to the bananas to be used as a mulch rather than to mature coffee trees themselves.

With the exception of an area in East Kilimanjaro, where a potash deficiency is being investigated, the soils are well supplied with other major elements and no significant responses have been obtained.

Trace Elements

In the main coffee-growing areas of the Northern Province, zinc and manganese deficiencies are suspected. Trials are at present being undertaken to correct these symptoms.

It has been shown that 'dieback' and 'blacktip', which occur in the Mbozi area in the Southern Highlands, are caused by combined boron and zinc deficiency diseases. Sprays containing these two micro-nutrients have trebled yields on the red earth type and increased them by 50 per cent. on the volcanic soils.

Insect Pests

Arabica coffee in East Africa is subject to attack by a fairly wide range of insect pests, many of which can cause serious losses; however, the majority can now be effectively controlled by modern insecticides.

A few years ago, white coffee borer (*Anthores leuconotus* Pasc.) became a grave threat to the industry, particularly at the lower and middle elevations, but, mainly due to the work of Tapley at Lyamungu, who achieved good results from applications of dieldrin, the spread of the pest has been halted and it is now only of minor importance where control measures are carried out. One application of dieldrin will give a good measure of protection for 27 months.

Intensive campaigns are waged against the pest but it is virtually impossible to eradicate it completely as wild host trees (chiefly small trees and shrubs growing in the riverines) always carry a basic population which cannot be exterminated. Adult beetles, which generally emerge from the stems of coffee trees during the long rains in April and May, and again during the short rains at the end of the year, lay their eggs beneath the bark near ground level. The larvae, which hatch out about three weeks later, ring-bark the stem for a few months before entering the wood, where they tunnel into the roots and up the stem for about two years, causing much damage, which invariably results in severe debilitation of the trees.

Frequent control measures are necessary against antestia (*Antestiopsis lineaticollis*) in order to reduce their numbers to reasonable proportions; it has been estimated that if three antestia are present per tree a reduction in yield of approximately 25 per cent. can be anticipated. The pest causes damage by sucking the sap from green cherries and at the same time it introduces the fungus, *Nematospora coryli*, which rots the beans.

Another pest which also damages the cherry is the coffee berry moth (*Thliptoceras octoguttalis*). One caterpillar can destroy 40-60 cherries by eating out their insides. This pest has only recently become of economic importance.

Green scale (*Coccus africanus*) and various species of mealybug sometimes cause damage to young trees but control measures are seldom necessary. They are partially dependent for their survival on attendant ants (*Pheidole punctulata*) which protect them from their natural predators. *Planococcus kenyae*, the extremely serious Kenya mealybug, is only to be found in the comparatively small coffee areas in the Lake Province of Tanganyika.

During hot, dry weather thrips (*Diarthrothrips coffeae*) are apt to multiply extremely rapidly as soon as the temperature rises above the critical limit. The pest feeds on the underside of leaves, giving them a silvery appearance, and in a bad attack trees can be completely defoliated.

Leaf-miner (*Leucoptera* spp.), like thrips, can also induce heavy leaf-fall caused by the larvae tunnelling into the leaf tissues, with the result that the trees become weakened due to lack of proper nutrition. During hot weather the life cycle takes about a month and each generation is capable of increasing its numbers 25-fold. Leaf-miner is normally kept in check by parasites, but serious outbreaks occur occasionally when the biological complex is upset for reasons which are not yet fully understood.

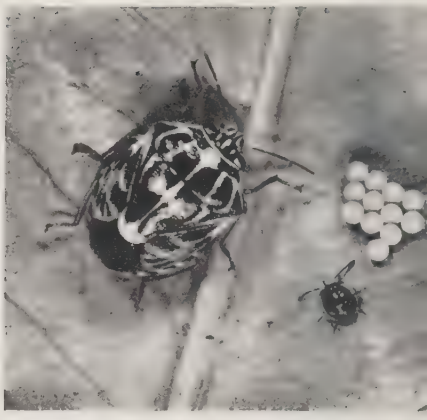
Stephanoderes (*Hypothonemus hampei*) and lacewing bug (*Habrochila placida*) are both pests of minor importance in Tanganyika as they only occur in the Lake Province. Both are serious pests in Uganda and parts of Kenya and for this reason there are restrictions on the moving of plant material within the three East African Territories. Stephanoderes is a small beetle which causes damage by boring into the green cherry, and the lacewing bug seriously damages the leaves.

Nearly all these pests can now be controlled effectively by the use of insecticides, and while it is not possible to eradicate a pest entirely by this means, numbers can be reduced to reasonable proportions.

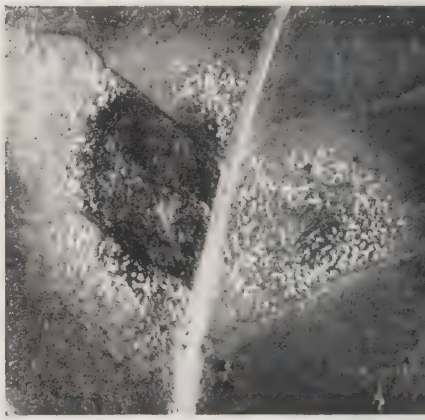
The discovery of dieldrin as an efficient control for white coffee borer has prevented widespread destruction of coffee trees, for this pest was, until a few years ago, a serious menace to the entire industry. Dieldrin is normally either sprayed or painted with a brush on to the lower part of the main stems. Mature trees should be treated each year for two consecutive years and thereafter in alternate years, unless subject to reinfestation from surrounding areas, in which case the treatment should be applied every year. Young trees should be treated annually until maturity. This treatment with dieldrin is also effective in controlling ants attendant upon mealybugs and scale insects.

Dieldrin is also replacing DDT for the control of

Damage caused by white coffee borer, Anthores leuconotus.



Adult antestia, Antestiopsis lineaticollis, *with young nymph and eggs.*



Coffee leaf attacked by rust, Hemileia vastatrix.

antestia, although the latter is still widely used in Tanganyika, especially on native holdings where hand sprayers are normally used for application; on the larger plantation scale, mechanical spraying machines are in common use. It is of interest to note that synergised pyrethrum is preferred to DDT or dieldrin in Kenya, where the lack of persistency does not interfere with the biological complex to the same extent. The residual effect of DDT and dieldrin in that colony is considered to take undue toll of the parasites of the mealybug (*P. kenyae*) prevalent there. Until comparatively recently, DDT was almost exclusively used for the control of thrips, but in the Oldeani district the pest is showing a marked resistance to the chemical and it has now become necessary to spray with dieldrin instead.

As all insecticides are applied by native labour, chemicals with high mammalian toxicity cannot be used. This precludes the use of most of the organo-phosphorus compounds, with the notable exception of diazinon which has proved effective in the control of leaf-miner.

Weedkillers

Weeds can be responsible for large economic losses in yield mainly because they compete with the crop for available moisture in the soil during dry weather. Although the average annual rainfall at the Coffee Research Station is approximately 60in., it is badly distributed over the year and falls mainly during the long rains in April and May. During the remainder of the year, rainfall is generally the main limiting factor to increased yields, and the best method of conserving moisture is to apply a mulch of banana trash and prevent weed growth competing with the coffee. During the rains, however, an overall cover of annual weeds is to be aimed at in order to bind the topsoil together and prevent erosion; the tops of the weeds should then be kept slashed back to just above ground level.

A thick mulch not only helps to prevent erosion but also inhibits weed growth for a considerable time, in addition to its primary function of conserving soil moisture during dry weather. It has been estimated that the amount of

labour saved in weeding due to the smothering effect of a mulch amounts to 27-30 man-days per acre per year. Once weeds start to grow through a mulch it is difficult to destroy them by the normal method of hoeing without breaking down the mulch at the same time, by unavoidably incorporating it with the topsoil and thereby reducing its effectiveness as an insulation against the evaporation of soil moisture; chemical methods of weed control are therefore particularly useful under these conditions. It should be noted that elephant grass, *Pennisetum purpureum*, can be very troublesome unless it is very well rotted, as the stems take root at the nodes.

Hormone weedkillers can be used in mature coffee plantations where broad-leaved weeds are the main problem, but this inevitably leads to an increase in the grasses, which are much more difficult to control with chemicals. Under slightly different conditions in Kenya, a mixture of PCP and 2,4-D has given good control of mixed monocotyledenous and dicotyledenous annual weeds in both mulched and unmulched coffee, but, unfortunately, PCP has been found to affect the liquoring qualities of coffee by producing a 'bricky' flavour and is not universally recommended. Results in Kenya also indicate that a combination of dalapon and 2,4-D controls annual weeds and checks couch grass, but that TCA cannot be used in established coffee as it causes severe damage to the trees. CMU applied as a pre-emergence (of weeds) spray has shown considerable promise in the control of weeds for a period of eight to 10 weeks.

Perennial weeds can be exceedingly troublesome and couch grass (*Digitaria scalarum*) is almost impossible to eradicate completely because the rhizomes can grow right under the coffee trees. A field experiment at Lyamungu Research Station has been thoroughly weeded annually for 20 years but the couch grass still survives. Unfortunately, it cannot be killed effectively with herbicides in established coffee without seriously damaging the trees, but it should also be remembered that the removal of couch grass with forked hoes also causes a severe set-back.

The main use of chemical weedkillers for the eradication of perennial weeds must be in the clearance of land before planting; for this purpose TCA should be used at approximately twice the strength of dalapon to achieve the same effect. Promising results have also been obtained when dalapon has been applied at low rates to young growth of couch grass which is just beginning to appear after the land has been ploughed. Knot grasses (*Cyperus* spp.) are very resistant to herbicides even at high dosage rates, but *Kyllinga controversa* can be controlled by the application of CMU.

Fungicides

Leaf rust (*Hemileia vastatrix*) is quite the most serious disease of coffee in East Africa and, although many other diseases occur, they are not at present of sufficient importance to warrant the use of fungicides for their control. Debilitated plants are much more susceptible to attack than strong, healthy ones and severe infestations of *Hemileia* occur on trees which are exhausted due to over-bearing, neglect or an unsuitable environment.

An infection of *Hemileia* during the short and long rains is almost inevitable but, provided the trees are in good condition and fungicides are properly applied, the disease seldom reaches serious proportions. The first symptoms are orange-yellow spots on the under surface of the leaves which spread and coalesce until eventually the patches die and turn reddish-brown in colour. In a bad attack the leaves fall off and the trees may become almost entirely defoliated; if a heavy crop is being borne at the time it is sometimes advisable to thin out the crop so that the trees will not become exhausted.

Spores, which are readily blown about in the wind, settle on a leaf and, if sufficient moisture is present, start to germinate. Mycelium then gains entry through the stomata on the lower surface of the leaf and the fungus becomes established, but it is unable to penetrate the tough upper cuticle. For this reason, it is important that when spraying care should be taken to cover the undersides of the leaves.

A predisposing factor in an attack of *Hemileia* is that the surface of a leaf must remain wet for 24 hours to enable spores to germinate. These conditions normally only occur during the rains when protective measures must be taken to kill the spores. Copper fungicides are applied at the beginning of the long rains and again in the short rains after the first flush of new leaf has emerged. In order to obtain a good coverage of the leaf under-surface, and to economise in the material, the trees should first have been pruned. Various types of equipment are used for application including hand pumps, knapsack sprayers, high-volume spraying machines driven down the rows, stationary machines with four or more long hoses connected to lances, and air-blast machines. These latter are probably the most satisfactory as the turbulence gives a good overall leaf cover.

Bordeaux mixture is the most commonly used fungicide but other proprietary copper sprays are becoming more popular as they obviate the laborious mixing process. An experiment at the Lyamungu Research Station failed to reveal any differences between various types of fungicides applied at the normal rate of 1 per cent. equivalent of Bordeaux mixture, and it can be assumed that they are all equally effective. Under rather different conditions in Kenya, a 2 per cent. spray is often applied after the rains; this is a 'tonic' spray to prevent leaf fall, and is independent of the applications against *Hemileia*. Normally, copper sprays are applied in about 180gal. of water per acre; using air-blast machines, however, copper oxychloride in non-phytotoxic white oil has been applied at a rate of as little as 3gal. per acre.

To summarise, for the most part, fertilisers are normally only applied in comparatively rare instances to correct specific problems, and are not used as routine practice. All the common pests of economic importance can be controlled efficiently with modern insecticides, but so far as disease is concerned, copper fungicides do not provide the complete answer to the control of *Hemileia*, as they can only kill germinating spores before they penetrate the leaf.

Economics and Agriculture. ANNE MARTIN. Routledge & Kegan Paul, London. 21s.

This book is intended primarily for 'students of agriculture who are turning to economics for the first time'. It falls into two parts. The first deals with 'those parts of economics that are most directly relevant to agriculture', whether the object be the study of the individual farm or the agricultural economy as a whole. The relevant chapter headings are: Price, Demand and Supply; Costs; Forms of Competition; Economic Rent and Profits; and Economic Efficiency. It must be a comforting thought to students that these essential parts of economic theory can be adequately discussed in less than 80 pages.

It is only within recent years that the study of farm organisation and management has come to be regarded as an important and integral part of a complete agricultural curriculum. In the application of both the physical and biological sciences to the practice of farming, a thorough grounding in the basic sciences —chemistry, botany, zoology and so on—has long been considered necessary, and it is the economist's contention that a full appreciation of the many complex problems that arise in the study of farm organisation and management is impossible without a full understanding of the relevant parts of economic theory. The author has set out to meet this requirement rather than to write yet another book on economics and in this she has succeeded admirably.

The book is attractively written, the mathematical treatment has not been overdone and mainly agricultural commodities have been used to illustrate the operation of the economic theories presented. It may be urged that the author has not cast her net quite far enough and not all economists will agree with her decision not 'to follow the custom of dividing the costs into the broad categories of land, labour and capital', but bearing in mind her primary objective it must be said that both the field and method of discussion have been wisely chosen.

It is a common criticism of economic theories that it is apt to be very difficult to apply them effectively in the world of industry and that this is particularly so in agriculture. For example, after a lengthy analysis of the theory of equi-marginal returns, the author points out that 'we may emphasise the great difficulties that beset the farmer who attempts to follow these rules for maximising his economic satisfaction', because the estimation of both the marginal costs and the marginal revenues may be extremely difficult. This frank admission of the gulf that may exist between theory and practice disarms a deal of criticism and lends support to the view that, apart from its practical application, the study of economic theory provides a valuable intellectual exercise in disciplined thinking and in the logical analysis of a large number of complex and closely interdependent factors.

On one relatively small point the author lays herself open to criticism. She comments upon the differences in the terminology of the accountant and layman and of the economist but the accountant will be surprised to learn that in computing the cost of milk production he would ignore home-grown foodstuffs because these are 'not covered by any monetary transaction', and the agricultural economist will be even more surprised to learn that, in the author's view, the home-grown foodstuffs should be charged on the basis of what it would have cost to buy them.

The second part of the book consists of two chapters on Agriculture and the Public Policy and a final chapter on Land Tenure. Under Public Policy, the author examines two questions: first, why is it that so many governments in so many countries have found it advisable to give some special help to agriculture and, secondly, what different methods of giving this help have been tried? Obviously, these are questions which make a very wide appeal—to students, farming leaders, legislators and the general public—and they are discussed with remarkable facility and lucidity and with complete objectivity.

The basic reason for intervention by the state is that 'the agricultural sector of the economy of most countries suffers, by comparison with the industrial, from both a lower income per head, and an income which is more variable over time' and it is shown that these disabilities are, to a greater or less degree, due to conditions inherent in agriculture and therefore unavoidable. The author lists seven different methods that have been used to eliminate, or at least alleviate, these disabilities and discusses each in turn, with a wealth of examples from all over the world. No attempt is made to assess the effectiveness of the different methods but this is probably a superhuman task. How, for example, could one measure the net effect on the agricultural economy of government aid for advisory and research work?

In the final chapter, the author gives a clear, yet concise, account of the systems of land tenure that are found throughout the world. It is shown that there are many modifications of tenancy and owner-occupiership as they occur in Great Britain and that these modifications generally have their origin in political action, although the reasons for the changes are likely to be partly economic and partly social.

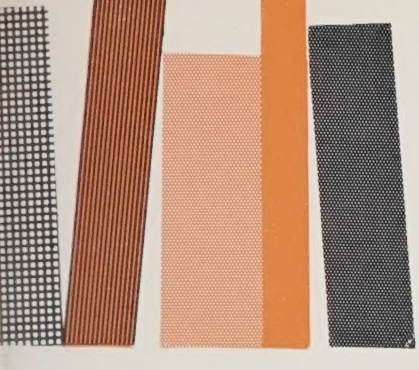
The book is beautifully produced and it is hoped that it will have the wide circulation which it so thoroughly merits.

JAMES WYLLIE.

The Insect Pests of Cotton in Tropical Africa. E. O. PEARSON. Empire Cotton Growing Corporation and Commonwealth Institute of Entomology, London. 40s.

E. O. Pearson is Director of the Commonwealth Institute of Entomology, London. For many years he was associated with the Empire Cotton Growing Corporation for whom he worked as an entomologist in East Africa, and he has studied cotton insects during visits to most of the other cotton growing regions in Africa, south of the Sahara. With this background, he is exceptionally well fitted to write about cotton insect pests in tropical Africa.

For the first time, the very considerable amount of published



information on the subject has been brought together in one volume. Where relevant, the author has introduced data from sources outside the continent, particularly from India which has several insects in common with tropical Africa, and, when possible, the published information has been supplemented privately. These facts have been fitted into the author's own comprehensive experience of the problems to produce a book of high quality which is eminently readable and well presented.

In effect, the book is in two parts. There is a concise introduction to the origins and distribution of cotton in tropical Africa, based on the studies of Sir Joseph Hutchinson, which includes sufficient detail to provide a useful background for the interested grower or entomologist. There is also a valuable section entitled Insects and the Cotton Plant which, in less than 30 pages, gives an overall picture of the groups of insect pests which are involved, their distribution in the main African cotton growing regions, and a general review of the damage done by insects. Inevitably this is condensed, but it is nevertheless helpful as a lead into the detailed information concerning insects. In addition, a key to the principal disorders of cotton in Africa has been included. With its aid, and after a little practice, the non-specialist should be able to decide which of the main pests or diseases is responsible for observed damage symptoms. It is a most useful part of the book, but it would have appeared more appropriately as an appendix.

The second part is the real justification for writing the book. More than 120 species have been described in as full detail as possible; the limiting factor has been the paucity of information concerning some insects and it is unfortunate that more data are not available in the literature. As expected, the major pests are dealt with very fully, and although this satisfactorily reflects the emphasis of research it also reveals where further effort and resources need to be concentrated. There are detailed accounts, sometimes supported with histograms and graphs from various sources, of the following: *Earias biplaga*, *E. insulana*, *Diparopsis castanea*, *D. watersi*, *Heliothis armigera*, *Platyedra gossypiella*, *Helopeltis* spp., *Empoasca facialis*, *E. lybica*, *Aphis gossypii*, *Lygus vosseleri* and *Dysdercus* spp. For every pest, where possible, data have been given under these headings: Description, Life History, Habits, Status, Distribution, Damage, Parasites and Control. Chemical control measures are only briefly mentioned, although R. C. Maxwell Darling has contributed a review of experience with insecticides in the Sudan, as an appendix.

There are eight excellent colour plates which partly illustrate the life history of some African cotton insects, but it would have added considerably to the book if more than a quarter of the species described in the text (and at least all the main ones) had been depicted. The lack of available paintings, up to the standard of those already included, perhaps accounts for the situation. Nevertheless, it would have been worth providing photographs, even in black and white, of other pests and damage.

There is a comprehensive list of references: 784 are cited, which indicates how thoroughly the literature has been searched; and there is a good index.

One is disappointed to find that so little information is given about the use of chemicals for controlling insects. This is perhaps an aspect of the uncertainty about using agricultural chemicals which seems to characterise entomological research in some under-developed territories and has resulted in over-reliance upon biological means of overcoming destructive insects. However, as it has been shown that insecticides can increase cotton yields, and as it has also been shown that biological control is not always reliable, this diffidence seems to be unrealistic. It is encouraging to find that in some parts of Africa, for instance Egypt, the Sudan, the French Community, the Belgian Congo and southern Africa, there is a growing awareness of the value of insecticides in cotton cultivation—perhaps because yield increases of at least 35-50 per cent over untreated controls have often been obtained, even under poor growing conditions. From research so far carried out, it is all too obvious that there is much to be learned about insecticide use and that, in particular, the timing of insecticide applications to supplement the beneficial effects of parasites requires more study.

In summary, this is a first-rate book with few shortcomings. As a reference work, it should have a place on the desk of every agricultural officer connected with cotton production, and of every up-to-date grower in Africa, south of the Sahara. There is also a great deal of very valuable information here for cotton growers and agriculturalists in North Africa, the Middle East, Pakistan, India, and S.E. Asia, and undoubtedly it would be interesting to many in the Americas, although not relevant to all their problems. More than this, it provides the research worker with a concise picture of what has been found out to date and by implication indicates what kind of new work could profitably be undertaken. There is no doubt that this will be a standard work for many years to come.

N. M. G. Bell.

Agricultural Botany. N. J. Gill and K. C. Vear. Duckworth & Co. Ltd., London. 63s.

College students of agriculture understandably tend to show an affinity for matters affecting the working farmer and often deplore time devoted to academic exercises. All too frequently botany comes into this category. That plant science can be and has been of very real value to the farmer is clear enough, but it is a matter of common experience that students tend only to heed instruction from men who are able to show how their science can be applied in the field. Much of the information, of which there is a great deal, in the 600-odd pages of this book is devoted to this objective and the reader quickly gains the all-important impression that the authors are not only competent botanists but carry a little muck on their boots as well.

One aim of the authors has been to satisfy the requirements of diploma and pass degree students in agriculture. For agricultural botany this is difficult to compass in a single volume but it may be said at once that this is one of the most satisfying attempts to date and is, moreover, a book which the young farmer might usefully acquire as resident consultant in his farm office.

The book is divided into four sections which deal with Crop breeding and Improvement, Crops, Weeds, and Diseases of Farm Crops. The latter includes a clear and concise account of plant virus diseases. A nicely balanced treatment has been achieved and although one may deplore the relatively little space devoted to crop physiology, it must be admitted that

many of the recent developments in this exciting field are, as yet, little more than of potential significance for farming.

The merits and demerits of crop varieties remain perennial talking points for growers and seedsmen, and here is given a most lucid account of the botany and blood relationships of these cereal varieties, variety trials and seed production—much of it recent information stemming from many of the important publications of the National Institute of Agricultural Botany.

In these days when the molecules of weed-killers are literally put together with the object of striking down specific plants, the intelligent farmer needs to identify weeds with greater precision than ever before. Of the greatest value in this connection are the excellent line drawings by Janet Maclagan of weeds and weed seedlings.

Photographs are costly to reproduce and are therefore few in number, but in future editions it may be hoped that some good photographs, adequately labelled, of mitosis and meiosis might be substituted for the first two figures, which are line drawings unworthy of the book. If farmers are to be trained in biology at all, they should certainly be given the opportunity to reflect on the convulutions of the chromosomes, as well as on the less spectacular particles of the tobacco mosaic virus which are illustrated here.

The extent to which plant anatomy should be introduced into agricultural courses is often difficult to decide in view of the limited time at the students' disposal. In accordance with time-honoured practice the structure of economically important plant organs such as the potato and sugar beet is dealt with by the authors, but not, one suspects, with very great enthusiasm. The descriptions might, to advantage, be revised and some small inaccuracies eliminated.

There is a splendid encyclopaedic index which includes such intriguing entries as 'Topinambour' (Jerusalem artichoke), 'Tripping of flowers' (no floral dance, but pollination mechanisms in legumes), and such unlikely crops as 'aubergine' and 'pe-tsai'.

To students, farmers, and the many whose work may be concerned with weed and disease control or the seed trade, this book can be heartily commended. I. W. SELMAN.

The Control of Pests and Diseases in Agricultural and Horticultural Crops. G. L. HEY and K. MARSHALL. Vinton, London. 12s. 6d.

This is a useful little reference book, meant for the not very technical but up-to-date grower, and worth having as an introduction to the pests and diseases which are commonly encountered in agriculture and horticulture. Students should also find it helpful. Although primarily for the United Kingdom, it is also relevant to other areas with similar conditions.

Its merit lies in its practical approach, both to insecticides and fungicides and to pests and diseases. The products are described by their common names (not trade marks), the pests or pathogens that each controls are mentioned, and the formulations commonly available and the normal dosage rates are given. In the case of insects and diseases, there is a short account of each (emphasising the importance of knowing the life history of the insects) and the means of control are stated. It is a pity that there are not more photographs of pests and diseases and their symptoms, and that those given are not better reproduced.

The sections on application methods and machinery really need to be expanded to be of real value. It would be better to stick to first principles only in a book of this kind and to go into the whole subject of spraying, fogging and dusting, of all agricultural chemicals, much more thoroughly in a separate volume.

In the next edition, a section about handling agricultural chemicals might well be included; an elementary book of this kind needs rather more detail than is given. N.M.G.B.

Advances in Pest Control Research, Volume II. Edited by R. L. METCALF, *Citrus Experiment Station, University of California, U.S.A.* Interscience Publishers Ltd., New York and London. $12.50 or 94s.

The second volume in this useful series—the publishers state that there is to be a new volume of *Advances in Pest Control Research* every year—contains specialist monographs on 10 subjects of interest to research workers in the pesticide field. The subjects are selected from recent significant research trends related to all phases of pest control, with emphasis on the fundamental aspects, we are told in the preface. The contents of Volume II are as follows:—

The fluid kinetics of application of pesticidal chemicals, by R. P. Fraser, Imperial College of Science and Technology, London. Innate toxicity of fungicides, by S. E. A. McCallan and Lawrence P. Miller, both of the Boyce Thompson Institute for Plant Research, New York. Research advances in seed and soil treatment with systemic and non-systemic insecticides, by H. T. Reynolds, University of California. Isotope dilution techniques for the determination of pesticide residues, by Carl T. Redemann and Richard W. Meikle, both of the Dow Chemical Company, California.

Wool digestion and mothproofing, by D. F. Waterhouse, Commonwealth Scientific and Industrial Research Organization, Canberra. The relation of chemical structure to activity for the 2,4-D-type herbicide and plant growth regulator, by R. L. Wain, University of London. Chemical structure and activity of DDT analogues with special consideration of their spatial structures, by Randolph Riemschneider, Free University of Berlin. The spread of insecticide resistance in pest species, by A. W. A. Brown, University of Western Ontario.

The Reduction and Presentation of Experimental Results. J. T. RICHARDSON. British Standards Institution, London. 10s.

This book deals with methods for the reduction and presentation of the results of statistically designed experiments. Unless the experiment to which a reader of this book wishes to apply the methods contained therein is statistically designed, the various assumptions underlying the application of the methods will not in general be satisfied. It is gratifying to see great emphasis placed on this point both in the foreword and the text, and to see the assumptions so clearly outlined. The readers of this book should therefore not fall into the same trap as the readers of so many elementary manuals on statistical methods, of misapplying rules.

There was, until the publication of this excellent little book, a real need for a concise statement of generally accepted procedures for reducing and presenting the results of experiments in all scientific and technicological fields. This book admirably fulfils that need. In a mere 38 pages which can be read quickly and intelligibly by anybody whose task it is to perform experiments, the reader is introduced to such notions as arithmetic mean; range; standard error; variance; degrees of freedom; confidence intervals and limits; frequency distribution; histogram; and normal distribution.

Rules for use in the condensation of data of one variable only are given, but no mention is made of any techniques associated with the analysis of variance. N.F.

Flame in the far desert

Today, a spreading yellow stain: advancing, enlarging, flowing together, smouldering under the desert sun. Tomorrow—if not extinguished—a searing, consuming flame, flying on the breast of the wind, fiercer by far than the ever-burning fires of Baba Gurgur in Irak, a plague borne on a thousand million wings.

From time immemorial, the desert locust (*Schistocerca gregaria* FORSK.) has scourged, year by year, a vast sweep of Africa and Asia. Through bitter centuries, men of many tongues have watched helplessly and without hope as the greenness was stripped from the earth.

Today the battle is being fought on more equal terms—and with mounting success. By international co-operation. By swift action based on shared information and intelligence. By the use of the most advanced and powerful insecticides science has to offer, such as aldrin and dieldrin, developed by Shell.

Aldrin, spread before the advancing, wingless hoppers, has been used successfully in many locust-infested areas of the world. Now, dieldrin—most persistent and versatile of modern insecticides—is being employed in a new technique which reduces both transportation and handling costs. Applied at extremely low application rates as a vegetation drift spray through a simple attachment to the exhaust pipe of a light vehicle, it has obtained high kills over periods of up to 36 days or more after only one treatment. Dieldrin retains its toxicity over long periods: this important Shell insecticide can *wait* for the fire to reach it to be extinguished.

dieldrin

Powerful against the Desert Locust, powerful against the vectors of malaria and other insects which carry disease to man, powerful against the grasshopper plagues of South America. Such is dieldrin, one of the six pesticides developed by Shell for world-wide use. Between them, aldrin, dieldrin, endrin, Phosdrin, D-D and Nemagon control virtually every major pest. ***Whatever Shell does, Shell does well.***

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